War Surgery

Field Manual

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Cover photo

The boy has a comminuted AK47-bullet fracture of the humerus with radial nerve injury and "drop hand" - a classic injury. The Trueta-type plaster cast drains his debrided wound.

War Surgery

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War Surgery, field manual is published by
Third World Network, a grouping of organizations and individuals involved in Third World and development issues.

For information, address to Third World Network, 228 Macalister Road, 10400 Penang, Malaysia. Tel: 604-2293511 Fax: 604-2298106

Notice
Although **War Surgery, field manual** encourages non-graduate health workers to engage in war casualty management, the manual cannot replace practical instruction by qualified experts. Neither the publisher nor the authors of this volume are responsible for damage done by unqualified implementation of the described procedures.

Library of Congress Cataloging in Publication Data

Hans Husum, Swee Chai Ang, Erik Fosse.
War Surgery, field manual.
Includes glossary and index.
ISBN 983-9747-12-6 Pb, 983-9747-14-2 Hb
1. Wounds and injuries. I. Husum, Hans
II. Ang, Swee Chai. III. Fosse, Erik

Text illustrations: Hans Husum
Design and cover: Hans Husum
Typography and composition: AK Grafisk, 9710 Indre Billefjord, Norway
Printed by Phoenix Printers Sdn. Bhd., 6, Lebuh Gereja, 10200 Penang, Malaysia.

Foreword – why this book

War Surgery, field manual is written for health workers and doctors in the front line, as a how-to-do-it-yourself, and also as a training manual. It is on life- and limb-saving procedures, and on organizing war medical services in the field. We also hope it is useful to the experienced surgeon faced with mass casualties under difficult conditions with few resources.

There are other books on war surgery, mainly written for well-equipped armies and hospitals. This manual looks at surgery from a different angle – from the standpoint of deprived Third World communities caught in wars they did not ask for. As surgeons working with Afghan peasants, the Palestinians in refugee camps, guerrillas in rural areas in South East Asia – people caught in wars they did not start and are unable to stop – we should be truly depressed by the injustice of the situation: Poorly equipped local medical services in poverty-stricken areas and paramedics with little formal education are made to cope with injuries from the most advanced weapons of modern warfare. Logic would say that when a village or refugee camp is "blanket" bombed to saturation level, the people being injured there would stand no chance of survival.

But the reverse is true. We learn from our fellow health workers a whole new way of looking at problems. We should not simply look at the wounded in the way surgical textbooks have taught us – dividing the patient into systems. Because resources are so scarce, we have to look at the enormous healing capacity of the human body as our best "ally" – and look at surgery as a total supportive strategy to assist that healing capacity. And we should look at the injured person as someone who is not a passive recipient of medical attention. The patient is actively trying to help himself, and so are his family and friends. The patient and his community therefore become part of the medical team, as operation assistants, blood donors, nurses and physiotherapists. They also teach us how to use local food resources for nutrition, and how to improvise and "pirate" equipment which would otherwise be beyond their reach.

The wounded starts dying at the time of injury, and can only survive if he receives life support and surgery immediately. In the war zones of the Third World, who are the surgeons? We ourselves have to come to terms with the traditional hang-up that only qualified surgeons can do life-saving operations.

One of us had an Afghan peasant as a fellow surgeon, and the other a nurse as chief orthopedic resident surgeon. And it is our belief that if the "copyright and patent" on surgical knowledge are broken, then many more talented people will come forward.

With an experience drawn from 15 years working in various war fronts, and always under the constant teaching of the people we work with, we feel ready to synthesize what we learnt in the field, teaching materials from training courses we conducted, and our scientific medical background into this manual. Our book is written for and about the "little man" struggling under enormous odds, with very little to fall back upon. We can only admire his strength. His survival proves the effectiveness of his methods.

This manual is dedicated to him.

Hans Husum, 1994

How to use the book

War Surgery, field manual may be used in several ways

- As a bed-side surgical manual for specific injuries
- As a manual in anesthesiology
- To plan and organize wartime clinics
- To run training courses for medical staff
- For self-study

For non-graduates

All health workers managing war casualties – paramedics, surgeons and organizers – should know the basics of war surgery: how bullets act, how the body responds, and how we basically can assist the body to overcome the damage done by the weapon. This is the content of **Section 2** which we recommend everybody to study as a beginning. Do not let medical and technical terms scare you. They are all explained in the **glossary, p. 721.** Knowing the more common terms, you are able to analyze, discuss and communicate medical matters in a more exact way.

> **Points to note**
> Non-graduates should study the inlet points at the head of each chapter. They list the most important features of the topic concerned. Procedures not listed as "Points to note" are more difficult; you need more surgical experience and theoretical knowledge to perform them.

A manual in surgery

Use the black-edged pages: Table 1 on p. 37 (forward field management) and **Table 2 on p. 41** (clinic management) form the **manual index.** The tables list ways of managing specific regional injuries, whether you work with few resources (in a light forward clinic) or are better equipped (in a heavy forward clinic). The tables give references to pages of **Chapter 7 and Section 4** where the management procedures are discussed in detail.

Region / Type of injury	Light FC	Page	Heavy FC	Page
Closed fracture	Peritoneal lavage?	109	External fixation apparatus	478
	Sling compression	478		
	Traction	499		
	Plaster spica	475		
Complications to pelvic injury	Exploratory laparotomy. Drain	356		
– pelvic abscess	Exploration	480		
– buttock abscess	Management	588-596		
– organ failure				
Back				
Penetrating injury	Peritoneal lavage	109		
	Exploratory laparotomy?	307, 356		
Spinal fracture				
– stable	Debridement	312		
– unstable	Two-step surgery:			
	1 Debridement	312		
	Transport cast	311	→ 2 X-ray	308, 316
	Evacuation		Exploration	313
			Immobilization	317
Spinal cord injury	Transport cast	311	→ Exploration	313
	Evacuation		Decompressive laminectomy?	309
			Dura graft?	313
Complications to spinal injury				
– spinal hematoma	Exploration	313	Decompressive laminectomy?	309
	Control bleeding	317	Decompressive laminectomy?	309
– infection	Exploration. Drain	318		
– pressure wounds	Preventive measures	318		
– bladder contracture		319		
Upper limb in general	Evaluation of major injuries	238, 484		
	Exploration of the main bones, vessels and nerves			
	– shoulder	487		
	– arm	490		
	– elbow	495		
	– forearm, wrist and hand	504		
Upper limb soft tissue injury	Debridement. Drain	178, 180		
– minor	Fasciotomy			
– major	– arm	491		
	– forearm	502		
	Skin flaps	255		
	Muscle flaps	200		

See table on the opposite page, copied from p. 46.

Eg. the primary management of a patient with a deep bullet wound at the back

- The bullet or fracture fragments may have entered the abdominal cavity. Consider peritoneal lavage to find out. Peritoneal lavage should be done also in light clinics, the reasons for diagnostic lavage are discussed on p. 109.
- The spinal wound must be debrided. The debridement of penetrating spinal injuries is illustrated on p. 312.
- If the fracture is unstable with risk of secondary cord injury, it should be stabilized with plaster cast at the light clinic, p. 311, and the patient evacuated to a better equipped clinic for exploration and fixation p. 313 and 317.
- If the clinical examination and primary debridement reveal spinal cord injury, the case may be evacuated for complete exploration. How to repair dural tears and reasons for decompressive laminectomy are discussed on p. 313 and 309.

A manual in anesthesiology

With the anesthesia methods in **Section 6,** proper surgery can be done on all types of regional injuries. The equipment needed is simple and light, and all methods can be done in the field. But nobody should give anesthesia, not even simple procedures, without thorough knowledge, equipment, drugs, and practical training as detailed in **basic life support, Chapter 7.**

Textbooks for further studies: p. 713.

Ether anesthesia with EMO apparatus is a valuable supplement to the methods in Section 4, specially for major stationary clinics. Study M.B.Dobson: Anaesthesia at the district hospital.

Use the book to plan and organize wartime clinics

Chapter 1 evaluates several models of forward war surgical networks already tested in recent wars under different conditions. Although you cannot use them as blueprints, you can apply to your local setting the guidelines and the check list on p. 31.

Chapter 2 presents two levels of equipment for a forward wartime clinic. **Table 4 on p. 57** lists a minimum alternative with which you can manage at least 80% of all cases (light forward clinic), and a better but more expensive alternative (heavy forward clinic). **Table 8 on p. 68** lists the approximate consumption of medical materials at a forward clinic, foodstuffs excluded.

Chapter 42 lists food materials available in Third World countries, and discusses how to organize production of post-operative nutrients based on local foodstuffs.

Use the book to run training courses for medical staff

War Surgery, field manual is based on teaching material developed for training courses in war casualty management conducted in several Third World areas of conflict. There is, of course, no standard program on how such training should be run. The type of weapons used, the level of experience and theoretical knowledge among the local staff must be considered. Such is the framework of the author's training programs:

Programs for quality assessment: p. 697.

Levels of equipment, and consumption of medical materials: p. 57 and 68.
How to improvise: p. 70.

Train medical staff at three levels: p. 31.

Session one is our paramedic training program.

Use "Points to note" ahead of each chapter to guide the students' homework. Also devise tests and exams based on "Points to note".

Practical training is done on animals, and in the operating room.

First – let the students examine the local setting

- Collect local facts on the types of weapons and warfare, the distribution of injuries, the mean time-lag from injury to the first medical support, the death rate (within one hour, one day, and one week after injury), the rate of common complications (post-operative wound infections, gram-negative pneumonia, septicemia). Assess roughly the quality of forward casualty management based on these facts.
- Examine the general level of nutrition, and rates of common endemic diseases among the local population.
- Examine the experience of the local staff in basic life support: How many cases they have done, how they did them in detail, what kind of problems they faced. Formal education is no guarantee for quality – a surgeon's skill can only be checked at the operating table, and by the results and rates of complications his clinic has.
- Examine the technical resources and logistic capacity: The training must fit the medical network at hand. The students must learn how to carry out diagnosis, life support and surgery with the equipment available.

Second – define the target of the actual training together with the students

- Training paramedics: Agree on a list of exactly defined basic life support procedures which the students should learn during the training. Our proposal: p. 31.
- Training surgeons: We recommend concentrating the training on basic life-saving surgery. On p. 32. we list the minimum procedures a wartime surgeon should know in order to properly manage 80% of all casualties and run a forward surgical clinic.

Third – the training course

- Session one – basic life support:
  - The injury, and the response to injury: Chapter 3 – weapon physics; Chapter 4 – basic physiology; Chapter 41 – complications to injury and surgery; Chapter 42 – metabolism after injury and surgery; Chapter 20 – endemic diseases complicating the injury.
  - The practical procedures for basic life support: Chapter 5 – the examination; Chapter 6 – the sorting of injuries; Chapters 7, 8 and 9 – the technical procedures.
  - Some case studies are described in the book, but more should be included in the training course. Evaluate in detail patients managed by the local clinics; arrange student exams based on realistic case studies.

- Session two – basic war surgery: Chapters 10-16 – management strategy for the main types of tissue injury; Chapter 44 – prevention and management of infections.

- Session three – field anesthesia: Chapters 45-48; repeat Chapter 7 – basic life support.

- Session four – regional surgery: Chapters 26, 36 and 7 – emergency abdominal surgery; Chapters 38 and 39 – limb injuries; Chapter 21 – open skull fractures; and Chapter 40 – burns.

For self-study

The fundamental strategy of the authors – basic life-saving surgery – is discussed in Chapter 7. Here we argue why a model of very forward surgical support should be implemented. Let that be your entry to **War Surgery, field manual,** together with Chapter 3 – what is actually modern warfare.

To health workers from rich countries in the North going to work in Third World areas with few technical facilities: Study Chapter 2 – how proper management can be done with simple equipment; Chapter 41 – how post-operative monitoring can be done without much laboratory equipment; Chapter 42 – how advanced nutrition can be drawn from local resources; Chapter 20 – how local endemic diseases can interfere with surgery.

We want feedback from our readers

To make the next edition of **War Surgery, field manual** a better tool in health worker education, we ask you to kindly forward your comments, criticism and proposals about

- new items and procedures you recommend us to change or include in the manual
- technical information, new weapons, the injuries they cause, and how to respond with surgery
- your experience with this manual in training of staff
- your experience and proposals for organizing forward field clinics
- distribution, making the manual better available for those who need it most.

Forward your comments to

Third World Network, 228 Macalister Road, 10400 Penang, Malaysia.

Or, Dr. Hans Husum, 9710 Indre Billefjord, Norway.

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Section 3: General procedures

Section 4: Specific injuries

Section 5: Treatment after surgery

Section 6: Field anesthesia

Section 1

The war medical organization

Points to note – Chapter 1

The forward clinic should be mobile and light
- study the Afghan models: p. 27-29
- the one-man mobile clinic: p. 66
- equipment for forward clinics: p. 56-63
- clinic production of foodstuffs: p. 600, 618-624

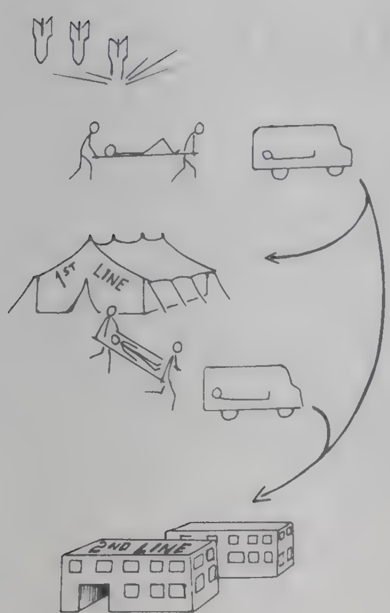
There is no fixed standard on how to organize
- examine the local conditions carefully: p. 30 and 31

Continuous training of staff is necessary
- train the clinic staff at three levels: p. 31
- control the quality of clinic management: p. 697
- how to use this manual in staff training: p. 10

1 The war medical network

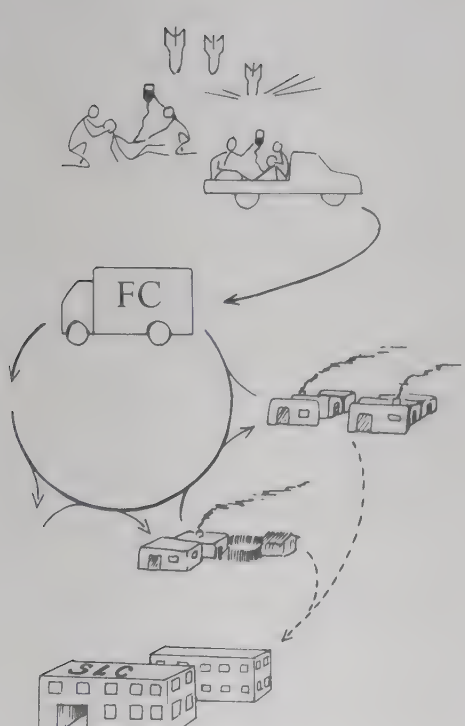
Examples from recent regional wars

The strategy of this manual is early and forward primary management of casualties. That means basic life support and primary surgery should be done within a few hours after the injury, within four hours at best. The basic model of organization is to locate the surgeon and the forward clinic close to the fighting fields. However, the design of this model in real life depends upon several factors, such as the actual military setting, the local popular support, the type of injuries encountered, and the skills and resources of your staff. The organization of the medical network is a main concern to the war surgeon and should not be left for military administrators to decide. You may draw some ideas from the examples listed below.

1


Two different basic models

1 The traditional model – the medical echelon: The standard model for casualty management in conventional armies consists of a rather rigid echelon. There is little or no medical support in the battlefield area. The first line hospital is not mobile and located far from the fighting grounds. Depending upon transport facilities there is a delay of hours from the time of injury till primary surgery. The first line hospital does general surgery only; many regional injuries (eye, head, chest) are not given primary surgery at the first line, but evacuated further to remote second line hospitals for specialized but delayed surgical service. Limbs and lives are unnecessarily lost due to hours of transport.

2


2 Our basic model – the medical network: The enemy controls the air, partly the ground and has vast technical resources. Our response must be high-quality medical management as close to the fighting grounds as possible, and a flexible and mobile network for casualty management and evacuation. Paramedics stabilize the casualties and even provide some life-saving surgery in the combat area and continuously during the evacuation. Our transport service is poor and the forward clinic (FC) is located close to the fighting grounds. It has to be mobile or semi-mobile for reasons of security. The FC should be able to provide definitive surgery for at least 80% of casualties with a minimum of delay from the time of injury. When patients are in a stable state after surgery (1-3 days) they are evacuated home or to villages for rehabilitation. Or to a non-mobile second line clinic (SLC) for secondary surgery.

Major permanent clinics → hospital infections → increased mortality

Death due to septic complications accounts for 10-20% of the war-hospital mortality. The risk of wound infections increases with long hospital stay. In major permanent wartime clinics one third of major wounds are infected with gram-negative strains within ten days after admission. In particular problems are caused by strains of pseudomonas and proteus resistant to most available antibiotics.

The one-man mobile clinic: p. 66.

> There is only one reason to centralize war surgery in major clinics: By tradition it is there you find the surgeon. Better apply a model of mobile surgery, decentralized clinics and early evacuation to rehabilitation centers. The surgeon is more mobile than a severe war casualty.

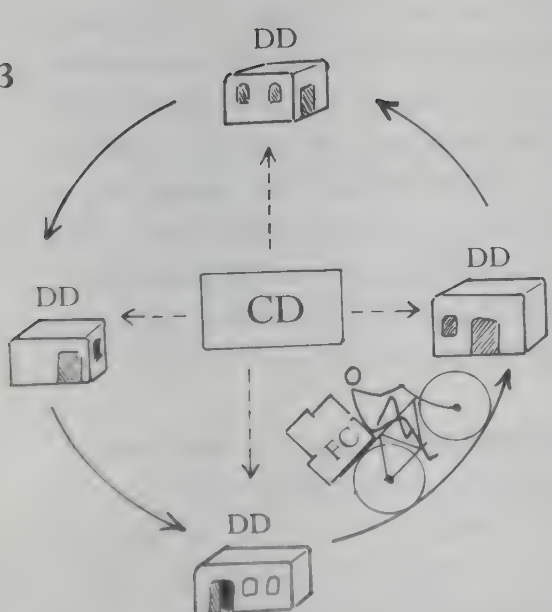
Applications of the network model

In an actual war scene the military events force you to improvise. In the Falklands/Malvinas war between Britain and Argentina in 1982 some British doctors in a small forward clinic found themselves trapped for several days without helicopter service; casualties could not be evacuated to the experienced surgeons at the second line clinic. So they had no choice but to do definitive surgery on all casualties admitted. After the war they published their surprise at the positive results of this forward surgery. You should not allow yourself to be trapped by the circumstances. Geography and climate, the military forces and positions on both sides, local popular support, actual supplies of water, food and energy – these are all factors that should be closely examined before you design a military medical network. Here are some examples from late regional wars:

Afghanistan 1985 – village area in the countryside

The conflict: Afghan resistance fighters against Soviet army and Soviet supported government forces. Soviet forces: total air control, bombs, air-to-ground rockets and aircraft gunfire against military and civilian targets. Heavy artillery at random against village areas. Ground control of main roads, mining of minor roads. Resistance Afghan forces: light weapons and mines only. Communication and transport by horse and bicycle. The geography: plains without woods or other cover against planes. Densely populated village area with mud houses. Some agricultural production. Extensive popular support with minimal enemy infiltration. Evacuation time to a second line hospital is three days.

3



3 Mobile light forward clinic (FC): Central depot (CD) with surgical equipment is stored underground. District depot (DD), each district had one paramedic responsible for forward medical management. He kept the district depot and joined the FC staff for training when the FC was working inside his district.

FC equipment
Total weight is 40 kg, carried on bicycles or horseback:
- General surgical instruments for four major debridements; instruments for abdominal surgery, external fixation of fractures, amputations, skull trephination, and vascular surgery
- Pedal suction and intubation set
- 10 000 ml Ringer infusion
- Drugs: antibiotics, analgesics, ketamine, diazepam, atropine, drugs for local and spinal anaesthesia
- Bandages and plaster
- One big kettle and primus heater for sterilization

• Headlights

This equipment enabled the FC to provide definitive surgery to any casualty. For mass casualties or planned secondary surgery, supplies were collected from the CD.

The central depot

It is a surgical unit of total weight 200 kg, available for the FC on horseback with twelve hours' delay. The surgical unit contained

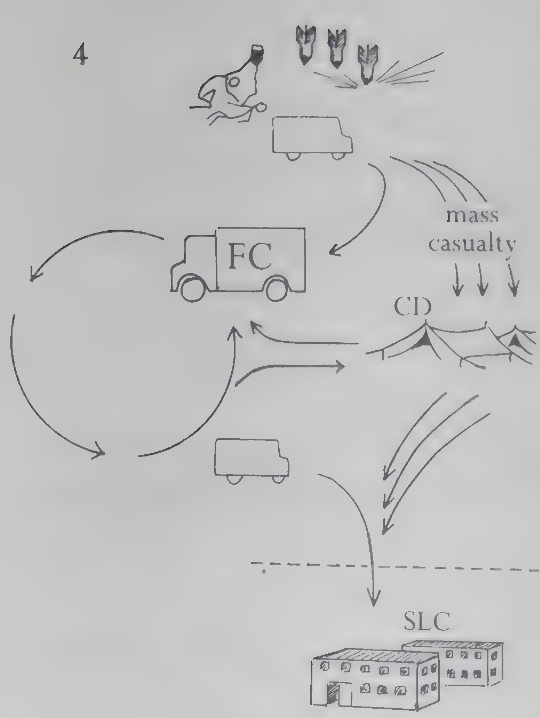
• Surgical instruments for another four major debridements
• Ether gas apparatus
• 50 000 ml infusion
• Electric generator and X-ray apparatus
• Blood-typing equipment

In case of planned attacks on Soviet posts, the FC was set up close to the fighting area. In unexpected Soviet attacks, the FC was called by courier. Surgery was done in village houses, mostly during the night due to enemy air-surveillance. After surgery patients were distributed in neighboring villages and monitored by the district paramedic every day and by the FC team every 3-5 days. The results proved this model to be efficient: 75 surgical operations were performed within two months, all patients given definitive treatment and secondary surgery at the FC. The mortality among cases admitted for surgery was less than 10%, the rate of post-operative infections was 10%. **The main strengths** of this model were its flexibility, its military security, the low rate of wound infections and low costs. **The drawbacks** were the delay in surgery due to problems of communication, transport, and limited capacity in a mass casualty situation.

The Jalalabad front, Afghanistan 1989-93

The conflict: Afghan resistance fighters holding Soviet-backed government army under siege inside the city of Jalalabad (city population 200 000). Pro-Soviet forces: close- and far-range fighting. Any type of ground- and air-to-ground weapons were used against the siege forces and villagers of the area, including delayed explosion bombs, anti-personnel cluster bombs and minefields, modern HE fragmentation shells and mortar bombs (p. 86). Air-surveillance day-and-night. Afghan resistance forces: hand weapons, mines, light mortars and short range rockets. Off-road transport by trucks and four-wheel-drive cars. Communication by wireless between the FCs, the ambulances and military units. The geography: plains with some woods. Village area with low agricultural output. The population was small with considerable Soviet infiltration. The time of evacuation from FCs to second line hospitals was 3-8 hours.

4



4 **"Mujahed Medical Center" at Jalalabad:** Ambulances manned with doctors and paramedics that did life-saving surgery and stabilized the serious cases before evacuation to the FC – a mobile truck operation theater for maximum of three cases at a time. The FC took supplies and staff from the central depot – with surgical service for mass casualties, store for instruments, infusions and drugs. Across the border were second line clinics and hospitals run by the resistance forces and international relief organizations.

Standard BLS kit: p. 64.

Each ambulance carried a basic life support (BLS) kit:
- Stethoscope, airways, face masks, suction unit, intubation set
- Bag and connections for ventilation, chest tube unit, naso-gastric tubes
- Instruments for venous cut-down, NaCl infusion 10 000 ml, plasma expander 2000 ml, large gauze packs and elastic bandages
- Drugs: Ketamine, analgesics, local anesthesia, diazepam, atropine, antibiotics
- Others: Splints, headlights

The FC truck carried three beds, three BLS kits; surgical instruments for four major debridements including instruments for abdominal surgery, skull trephination, amputations and vascular surgery; drugs and equipment for ketamine and regional nerve block anesthesia; battery-run electricity but no X-ray facilities.

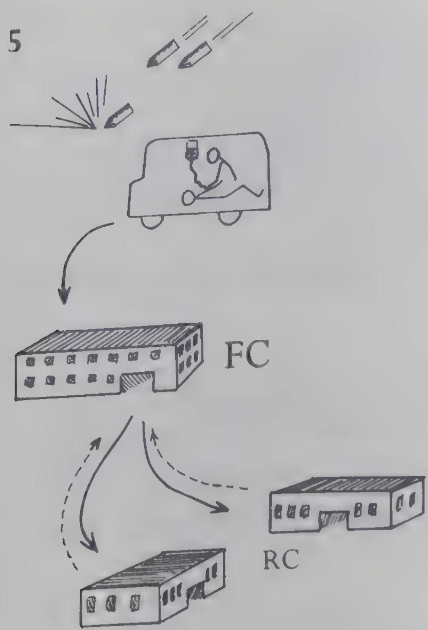
The central depot tent camp contained three tents for surgery, surgical instruments for four major and four minor debridements, infusion, drugs and bandages for 100 casualties, facilities for washing, sterilization and maintenance of instruments and equipment, electric generator but no X-ray facilities.

The mean delay from the time of injury to the time of ambulance medical service was one hour; the mean delay up to FC surgery was four hours. During periods of heavy air attacks the mean delay might be 24 hours. The main method of anesthesia was ketamine in sub-anesthethic doses. The FC forwarded the casualties to SLC as soon as life- and limb-saving surgery was done (within two hours after surgery). When the FC or the central depot was under direct military pressure war wounds were managed with fasciotomy and double drainage only, leaving definitive surgery for SLCs. The results: 5500 war casualties were managed and evacuated by this network; out of these 15% were classified as T1 injuries by triage (p. 123). The total mortality rate (those dead before reaching the network and those dying before reaching SLC) was 20%. The central depot tent clinic was able to manage mass casualties of 20 patients without serious congestion and delay. Seven staff members were injured during duty, three of these seriously. **The main strengths** of this model were its mobility and early BLS. **The drawbacks** were relatively high costs and the risk of enemy attacks on patients and staff.

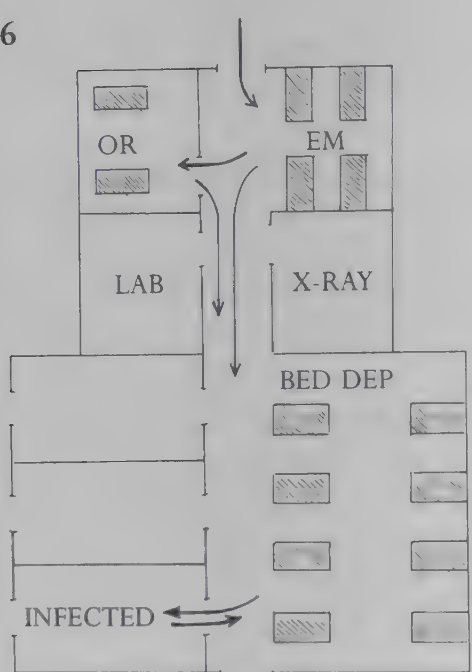
The siege of Tripoli, Lebanon 1983

The conflict: Palestinian and patriotic Lebanese forces under siege by Syrian and Israeli forces in the Lebanese city of Tripoli and the surrounding Palestinian refugee camps. The attacking forces (Syrian and Israeli): close-range fighting with ground-to-ground rockets, mortars, self-propelled cannons and naval artillery; extensive sniping; no air attacks or cluster weapons. The defending forces (Palestinian and Lebanese): hand weapons and some light artillery. Geography: Tripoli city had 200 000 inhabitants, many of them Palestinian refugees from camps outside the city; general shortage of food, fuel and medical supplies; extensive popular support to the resistance. The fighting area was on the outskirts of the city; evacuation time from injury to FC was less than 30 minutes. Further evacuation of casualties was impossible due to the siege.

5



6



5 **Palestinian Forward Hospital, Tripoli:** Ambulance with paramedics giving infusion during evacuation from fighting area to the FC – the forward hospital. Here definitive surgery was done on all casualties. When stable after the surgery (1-5 days) patients were distributed among rehabilitation centers (RC) inside the city to relieve the load upon the main hospital. From here they were readmitted to the hospital on an out-patient basis for later reconstructive surgery.

6 **The internal organization of the hospital:** Emergency department (EM) with four beds. All casualties were taken here for triage and stabilization, including urgent life-saving surgery. Operating room (OR) with three operating tables, fully equipped for general anesthesia. Bed department with 50 beds. X-ray and lab: mobile X-ray apparatus with manual developer. Laboratory for simple analyses, blood-typing and blood bank with 30 units of blood.

The Tripoli FC was located underground in a concrete building giving protection against artillery hits. The electric supply was sufficient and stable. The emergency department was always manned by the senior surgeon and the most experienced nurses. The operating theater was manned by three teams, each with one surgeon, one assistant doctor, two scrub nurses and one anesthesia technician. Each team could manage 10 operations/24 hours. The bed department was manned by two doctors and five experienced nurses on 24 hours duty. The surgeons made the first post-operative dressing themselves. The rehabilitation centers were manned with two doctors, four nurses and one physiotherapist each. The results: 1500 war casualties were admitted during 35 days. Out of these, 400 cases were hospitalized and given definitive primary surgery, the rest were managed as out-patients. The rates of early and late mortality were low. None of the in-patients or staff on duty was injured. **The main strengths** of this model were competent primary surgery without delay, and a high capacity for mass casualties. **The drawback** was the hospital being a target to attack, should the attackers gain air control a more mobile model with less capacity would have to be applied.

Guidelines for the organizer

- Flexibility: The medical network is not a fixed system. To be efficient and safe it must be as flexible as the military organization it serves.
- Command: Each network must have one and only one field officer in charge. A war surgeon should not leave important organizational matters to non-professionals; a committed senior war surgeon is also the best field officer.
- Planning: The military setting is unpredictable. The officer in charge must continuously monitor the following key factors to which the organization must respond.

Check list

- The quality of the enemy weapons
- Means of off-road transport. The time (exactly, in hours) used for casualty evacuation inside the area, in the dry season and during the monsoon, during day and night, during ceasefire and under air attacks
- The general health condition of the population

Advanced weapons, difficult evacuation and poor general health condition → arrange high quality FCs in very forward positions.

- The enemy aircraft capacity and air/ground surveillance
- Enemy night vision capacity
- The extent of enemy infiltration inside the area

Extensive enemy surveillance and military pressure → arrange very mobile light FCs.

- The extent of popular political support
- Civil medical service in the area

Good popular resources → arrange a network inside the area for post-operative management and rehabilitation.

- The available resources of food, water and fuel inside the area

Good nutritional resources → organize high-energy food processing inside the area.
Poor resources → concentrate on logistics.

Training of medical staff

Recommendations for staff training, also see p. 10, 581-583.

Forward, mobile surgical units must be able to work on an independent basis. This makes us focus on staff quality. For the senior surgeon, education of qualified junior officers on all levels is as important as his own surgical performances at the operating table. Some knowledge in matters of theory and medical routines is necessary. But first and foremost you train your staff by letting them take part and have responsibility for the day-to-day surgery and medical procedures; guided practical experience is the best teacher. As a general guideline, we advice you to educate medical staff on three main levels: First level – **Paramedics.** Second level – **Surgeon 1.** Third level – **Surgeon 2.**

Training of paramedics

They are the most numerous of the three categories of medical staff. Their main duty is to provide early and correct medical stabilization in the combat area and during evacuation up to the forward clinic. Experienced paramedics should be trained in:

- **Knowledge of weapons:** Study Chapter 3, know the weapons actually used in the local conflict.

- **Knowledge of physiology:** Study Chapters 4, 5, 6 and 17 to be able to do proper triage.

Basic life support procedures: p. 37.

- **Airways and respiration:** Study Chapter 7. Learn to evaluate the respiratory state of patients. Maintain free airway by oral airway and stable side position during evacuation. Provide rescue breathing, and assisted SIB ventilation. Do chest tubing and emergency laryngotomy.
- **Circulation:** Study Chapter 7. Evaluate the circulatory state of patients. Control external bleeding by compression, and proximal clamping of the main limb arteries. Control severe abdominal bleeding by emergency laparotomy and gauze packing. Insert bladder catheter, do venous cut-downs, give and monitor volume therapy. Calculate and monitor the in-out balance of fluids.
- **Analgesia:** In-field reduction and splinting of fractures. Give i.v. analgesics including low-dose intermittent ketamine.

The Injury Chart: p. 52.

- **Documentation:** Fill in the Injury Chart. To do so, a main part of the training should be clinical examination, evaluation and diagnosis of the most common injuries. For weeks the surgeons should let the students join in the triage and basic life support procedures at the clinic, give them responsibility, monitor and guide them closely.

Training of Surgeon 1

The Surgeon 1 should be able to run a forward clinic and manage basic life support and primary surgery on 80% of all trauma cases. The category of Surgeon 1 is the key factor and the foundation for any wartime clinic. Experienced and talented paramedics should be selected for Surgeon 1 training. The Surgeon 1 should know and manage the following:

- Basic knowledge of weapon physics, of the technology of common arms and ammunition.
- Perform triage, including triage of mass casualties.
- Local anesthesia, regional nerve block and ketamine anesthesia.
- Endotracheal intubation and emergency laryngotomy. Evaluate and manage penetrating chest injuries by chest tube and suction. Emergency thoracotomy and minor lung resections.
- Control of grave external bleeding by exploration and ligature of the main vessels. Perform blood-typing, cross-matching, direct transfusions and autotransfusions.
- Manage limb injuries by fasciotomy, exploratory incisions, debridement and drainage. Fracture management by dynamic traction, the Trueta plaster cast and cast-and-pins. Perform guillotine and flap amputations.
- Know the principles of emergency laparotomy: two-step surgery with gauze packing, tying or suture of intestinal wounds, and temporary abdominal closure. Divert the fecal stream by exteriorization of intestinal wounds, or diversion stoma.
- Manage free skin grafting and skin flap closure.
- A basic understanding of nutrition after surgery.
- Train paramedics.

The Surgeon 1 must know the details of anatomy and the essentials in physiology. But the essential training is clinical evaluation of patients and surgical evaluation of injured tissue; let the trainees perform day in and day out triage and surgery under your guidance.

Training of Surgeon 2

That training never ends. You will find the textbooks referred to in Appendix 4 valuable, as well as continuous studies of modern weapon technology. But again, real life experience is our main teacher. Stick closely to your patients. Monitor and dress your own cases after surgery. If possible, collect the late results of your surgery; register clinic complications, early and late mortality in order to assess at regular intervals the quality of your organization and your own skills. Never think you are too experienced to seek the advice of others; and to look for your own mistakes.

Staff care

- You do better with five fresh and hard-working staff members than ten exhausted ones. Train enough staff to offer them days off at regular intervals.
- Monitor the mental state of your staff members. At the first signs of depression (unrest and sleeplessness) do not hesitate to take them off duty for at least two weeks.
- Some people are not at all fit to cope with the stress of working in a forward medical position; they cannot concentrate on their duties and you cannot rely on the decisions they take. No matter how skilled they are, you do better to dismiss them from your forward teams.

Points to note – Chapter 2

Chapter 2 has the key tables to show you how this book can be used as a manual.

For the surgeon

- Forward basic life support for the main types of injuries: see Table 1 on p. 37. Find the actual procedures, and study them in detail in the black-edged chapters
- The surgical management of different types of injuries: see Table 2 on p. 41. Find the actual procedures, and study them in detail in the black-edged chapters
- For medical documentation, study and copy the Injury Chart: p. 52. The Patient Chart: p. 53 and 54. The Head Injury Chart: p. 55. And the Burn Case Chart: p. 566
- You can run quality-control programs based upon the information collected from the Injury Chart and Patient Chart: p. 700

For the organizer

- Recommended contents of BLS kits: see Tables 5 and 6 on p. 64-65
- Equipment for the one-man mobile clinic: see p. 66
- Equipment lists for light and heavy field clinics: see Table 4 on p. 57
- Assess how much materials your clinic will consume: see Table 8 on p. 68
- Local production of foodstuffs for the clinic: p. 600, 618-624
- Handle surgical instruments with care. Let technical staff study p. 69-72

2 The forward clinic (FC)

The patient starts dying at the time of injury. Our response is basic life support (BLS) and primary surgery with minimum delay. Consequently the FC is the most important unit in the wartime medical network. Quality and efficacy of the medical network depends totally on high quality FCs. This chapter describes three basic models of FC organization:

- **The light FC:** A light mobile or semi-mobile surgical clinic with staff and equipment able to do definitive primary surgery on 80% of all casualties.
- **The heavy FC:** A better manned and equipped clinic able to do definitive primary surgery on any wartime casualty.
- **The one-man mobile FC:** A backpack clinic with a complete BLS kit and simple surgical instruments. In skilled hands and with support from the local population, the one-man FC may handle close to 80% of all casualties.

The actual design of the basic models depends on the local setting. Examples of FC design: p. 27-31.

Organization of forward basic life support (BLS)

> **BLS in the battlefield – our objective:**
> Casualties should be in a stable medical state before the evacuation from the battlefield starts. Casualties should be maintained in a stable state all the way during evacuation. The longer the evacuation, the more advanced field BLS is necessary. Consider if surgical instruments should be included in the BLS kits (one-man clinic: p. 66).

Regard the medical support inside the battlefield and the evacuation of casualties from the battlefield as parts of the FC management. The surgeon in charge of the FC should also decide the routines for the battlefield management. Basic life support for serious cases may also include surgery, and some emergency surgical procedures should be done in the battlefield. The quality and extent of battlefield medical support will vary from one area to another depending on the intensity of the fighting, the weapons used, the mobility and military protection of forward medical staff, and the staff skill. The FC leader should continuously try to improve the battlefield BLS support from a **minimum level,** gradually include more advanced procedures and BLS kits as paramedics gain in skill, and try to reach an **optimum level.** Most of the surgical procedures listed in Table 1 are done within 30 minutes in the field by trained staff. This is thus a realistic goal for high-quality FCs.

Basic life-saving surgery: p. 130 and 153-161.

Staff-training programs: p. 10 and 31.

Table 1
Procedures in forward BLS support

Medical problem	Procedures minimum level	Page	Procedures optimum level	Page
Triage	Clinical examination	103		
	Triage of mass casualties	127		
	Documentation	52		
Airway obstruction	Assess critical signs	136		
	Head tilt and jaw thrust	136		
	Recovery position	137		
	Insert oral airway	136		
	Cricoid pressure	140	Endotracheal intubation	137
	Gastric decompression	139	Emergency laryngotomy	139
Breathing problems	Assess critical signs	136		
	Rescue breathing	141		
	Mouth mask-SIB ventilation	141		
	Gastric decompression	139	Close open chest wounds	344
			Temporary closure of abdominal wall wounds	359
Pain	Intermittent i.v. analgesia	142		
	Ketamine analgesia	151	Intercostal nerve block	673
			Chest tube	142
			Intrapleural anesthesia	674
Circulatory shock	Assess critical signs	148		
External bleeding	Gauze pack and compression	144	Explore and ligate major vessels	189
Internal bleeding	Central warming of cold patients	153	Emergency thoracotomy, aorta clamping	154
			Emergency laparotomy,	155
			abdominal packing	157
	Shock dress	145	Autotransfusion	270
	Dbl.large cal.i.v. lines	145		
	Intraosseous infusion	146	Venous cut-down	146
	Assess blood vol.lost	108	Peritoneal lavage	109
	Volume therapy in adults	148		
	Volume therapy in children	262		
	UPH monitoring, bladder catheter	582	Suprapubic bladder catheter	436
	Volume therapy complications	149		
Head injury	Assess critical signs	115		
	Monitoring, documentation	55		
	Airway management			
	Drug therapy	136	Endotracheal intubation	137
			Hyperventilation	295
			Volume therapy	144, 147

Medical problem	Procedures minimum level	Page	Procedures optimum level	Page
Spinal injury	Transport	310		
Limb injury	Fracture reduction and splinting	202	Emergency fasciotomy	177
Injury during pregnancy	Carbohydrate nutrition	152		
	Volume theraphy	449		
	Support breathing	449		
Blast wave injury	Monitoring	82	Lung injury management	82
			Abdominal injury management	83
Thermal burns	Volume therapy	559		
	Airway management	563	Endotracheal intubation	138
			Life-saving surgery	564
Hypothermia	Preventive measures	277		
	Rewarming	153		
			Manage circulatory complications	277
Hyperthermia	Cooling	279		
	Manage brain complications	295		
	Volume therapy	279		
Hypoglycemia, malnutrition	Carbohydrate nutrition	152, 609		
Drugs				
– adminstration	Intravenous	150		
	Intraosseous	146		
	Rectal	150		
– doses and side effects	Ketamine	149, 151		
	Diazepam	151		
	Morphine	151		
	Pentazocine	151		
	Metoclopramide	151		
	Routine antibiotics	644		
			Dexamethasone	82, 279
			Frusemide	82
– local anesthetics	Fracture anesthesia	152	Nerve block anesthesia	152
	Joint anesthesia	152		

Basic life support at the FC

Evacuation from the battlefield may be delayed; it may be a prolonged evacuation or complications may develop due to injuries missed in the battlefield triage.

- Senior surgeon: Take all cases for the FC to the emergency room and do fresh triage.
- Senior surgeon: Study the Trauma Protocol and evaluate the basic life support done in the battlefield and during evacuation.
- Senior surgeon: Order the basic life support to be continued for T1 and T2 cases until they reach the operating table. See Patient Chart below.

Basic life-saving surgery

It is a hazard to do surgery on a patient whose vital condition is poor or deteriorating. However, in some unstable cases emergency surgery must be done in order to establish stable vital functions. These emergency surgical procedures should be considered part of the basic life support.

Basic life-saving surgery: p. 130 and 153-161.

Time is the critical factor
Basic life-saving surgery can be done with simple standard equipment under i.v. ketamine anesthesia. The procedures must not be delayed and should be done by the surgeon at hand. **Notice:** even in the field basic life-saving surgery is done on dying patients or dying limbs when the alternative to non-intervention may be death.

There should always be one emergency kit sterilized and ready at the FC for emergency surgery. The emergency surgical kit should contain:
- One heavy BLS kit: p. 65
- One set for general surgery
- Several gauze packs 40x40 cm
- Equipment for autotransfusion

The BLS team

Light and Heavy BLS kits: p. 64.

The equipment should be standardized in **light** and **heavy** emergency kits depending upon the skills of the BLS team and the available resources. The kit should be packed in a solid soft bag easy to carry in the field by hand and as backpack.

To work efficiently and smoothly, and be able to cope with mass casualties, the staff should be organized in teams of three in the battlefield as well as at the FC. Each team is composed of staff working well together, one of them prefer ably senior and in charge of his staff:
- **Staff no 1:** The most experienced of the team members. Team leader. Takes

care of the airway management and respiratory support. Prescribes drugs and volume therapy. Responsible for training of no 2 and 3. Should stay with the most serious case/cases.

- **Staff no 2:** Takes care of the circulatory support.
- **Staff no 3:** Assists in establishing the i.v. lines. Takes care of drug administration according to prescriptions given. May leave the patient.

Guidelines for the battlefield BLS team

- The team works under pressure and needs an experienced team leader. His orders are to be followed strictly.
- More than one casualty: Even under difficult conditions, conduct triage before basic life support starts.
- Consider if emergency surgery is necessary. If so, remove that casualty from the area of heavy fighting and fulfill the procedures (Table 1) before he is evacuated to the FC.
- For all casualties: Fulfill the BLS procedures necessary before evacuation starts. It is impossible even to insert an i.v. cannula inside a moving off-road car.
- Fill in the Injury Chart before evacuation starts.
- Where long-time evacuation is expected: Give exact prescriptions for medical support throughout the evacuation regarding analgesia and infusion, as well as for complications that may arise.
- Continue active basic life support throughout the evacuation.

Management routines

The routines listed below are guidelines, they should be applied with care depending on the military setting, the casualty load, the staff skill, and the equipment at hand. The references are to pages where the procedures are discussed in detail.

Table 2
Routines for management of regional injuries at the FC

Region **Type of injury**	**Light FC**	**Page**	**Heavy FC**	**Page**
Head and face				
Open skull fracture	Debridement	297		
– with brain injury	Debridement of brain	297		
	Dura graft	298		
	or			
	Evacuation	→	Exploration	297
– in circulary shock			Emergency laparotomy or thoracotomy	155 154
Closed brain injury	Observation	301		
– with brain compression	Trephination	300		
Face soft tissue injury	Drainage	322		
	Primary suture	324		
	Flap reconstruction	335		
Face fracture	Temporary reduction	322		
	Evacuation	→	Primary fixation	325
Complications to skull surgery				
– brain edema	Management	302		
– infection	Exploration	302		
– skull hematoma	Exploration and drainage	300		
Rehabilitation after brain injury		638		
Neck				
Soft tissue injury	Exploration and drainage	303		
Larynx, trachea	Primary suture	304		
Cervical spine fracture				
– stable	Neck cast	316		
– unstable	Manual traction	310		
	Neck cast	316		
	Evacuation	→	X-ray	316
			Skull traction	315
Lesion of the spinal chord	Manual traction	310		
	Neck cast	316		
	Evacuation	→	X-ray	316
			Skull traction	315
Lesion of brachial plexus	Exploration	304	Secondary suture?	233
Vascular injury	Ligature?	304	Vascular reconstruction?	187
Complications to spinal injury				
– spinal hematoma	Exploration and drainage	317		
infection	Exploration and drainage	317		

Region Type of injury	Light FC	Page	Heavy FC	Page
Eye				
Penetrating	Topical antibiotics	333		
	Occlusion	333		
	Evacuation	→	Primary suture	336
			Subconjunctival antibiotics	337
Extensive penetrating injuries	Topical antibiotics	333		
	Occlusion	333		
	Evacuation	→	Enucleation	336
Complications to eye injury	Management	337		
Chest				
Minor lung injury	Analgesia	142		
	Intercostal nerve block	673		
	Exercises	630		
Hemo/pneumothorax	Chest tube	142		
	Wound closure	344		
Major hemothorax	Chest tube	142		
	Autotransfusion	270		
In circulatory shock	Evacuation	→	Thoracotomy, aorta cross-clamping	348
			Lung resection	346
			Closure with muscle flap	344
Major chest wall injury	Chest tube	142		
Blast wave injury	Observation. Drug therapy	82		
Cardiac tamponade	Pericardial incision	347		
Cardiac injury	Suture	348		
Complications to chest injury				
– respiratory failure	Management	588		
– lung abscess	Drain	350	Decortication	345
– persistent hemothorax			Decortication	345
Abdomen in general				
Penetrating injury				
– heavy bleeding			Emergency thoracotomy and aorta clamp	154
	Two-step surgery, one-hour limit	156		
	1 Gauze packing	365		
	Autotransfusion	270		
	Exteriorization	384		
	Central warming	153		
	Evacuation	→	2 Vascular reconstruction?	367
			Gastrostomy	369
			Definitive surgery: See below	
	or			
	2 Ligature. Resection	367		
	Definitive surgery: See below			

Penetrating injury				
– stable state	Peritoneal lavage	109		
	Exploratory laparotomy	360		
	Definitive surgery: See below			
– long evacuation	Emergency laparotomy	157		
– retroperitoneal hematoma	Peritoneal lavage	109		
	Mobilize and explore intestines	360		
	Beware!	417		
Blunt injury	Peritoneal lavage	109		
	Exploratory laparotomy?	356		
Injury to the abdominal wall				
– minor	Debridement. Suture	359		
	Peritoneal lavage	109		
– major	Two-step surgery:			
	1 Temporary closure	359		
	Relief suture	370		
	Evacuation	→	2 Definitive closure with muscle flap	201
Injury to the diaphragm	Suture. Chest tube	346, 142		
Injury to the small intestine				
– minor	Suture. Drain	381		
– major	Primary resection. Anastomosis	378		
	or			
	Two-step surgery:			
	1 Exteriorization	384		
	Evacuation	→	2 Definitive surgery	378
Injury to the colon				
– minor	Suture. Drain	382		
	Diversion stoma	384		
	Closure of stoma	388		
– major	Two-step surgery:			
	1 Gauze packing	365		
	Exteriorization	384		
	Diversion stoma	384		
	Evacuation	→	2 Resection. Anatomosis	386
	Closure of stoma			
Injury to the liver				
– minor	Drain	394		
major	Two-step surgery:			
	1 Gauze packing	394		
	Drain	394		
	Evacuation	→	2 Debridement. Suture	394

Region Type of injury	Light FC	Page	Heavy FC	Page
Injury to the stomach				
– minor	Naso-gastric tube. Drain	403		
– major	Two-step surgery:			
	1 Naso-gastric tube	403		
	Gauze packing	365		
	Evacuation	→	2 Definitive surgery	401
	or			
	2 Suture. Drain	401		
	Feeding gastrostomy	369		
	Feeding jejunostomy	403		
Injury to the duodenum	Two-step surgery:			
	1 Gauze packing	365		
	Naso-gastric tube	403		
	Artificial fistula	403		
	Feeding jejunostomy	403		
	Evacuation	→	2 Exploration. Suture	364
			Reconstruction	404
Injury to the biliary tract	Drain	393, 396	Resection	396
			Cholecystectomy	395
Injury to the spleen				
– minor and major	Splenectomy	411		
Injury to the pancreas				
– minor	Drain	417		
– major	Drain	417	Resection. Drain	418
Injury to the kidney				
– minor	Drain	424	Exploration. Debridement	425
– major	Two-step surgery:			
	1 Gauze packing	365		
	Drain	366		
	Evacuation	→	2 Resection. Suture	425
			Nephrectomy	425
Injury to the ureter	Two-step surgery:			
	1 Drain	368		
	Bladder catheter	436		
	Evacuation	→	2 Ureter catheter	423
			Reconstruction	426
			Nephrostomy	426

Injury to the urethra	Marsupialization	437		
	or			
	Suprapubic catheter	436		
	Evacuation	→	Reconstruction	436
Injury to the bladder	Primary suture	435		
	or			
	Two-step surgery:			
	1 Bladder and suprapubic catheter	436		
	Gauze packing	365		
	Drain	368		
	Evacuation	→	2 Reconstruction	435
Injury to the female organs	Resection	453		
	or			
	Two-step surgery:			
	1 Gauze packing	365		
	Drain	368		
	Evacuation	→	2 Resection	368
– injury to the pregnant uterus	Curettage	451		
	Section	452		
Injury to the male organs				
– minor	Primary suture	442		
– major	Evacuation	→	Reconstruction	443
Complications to abdominal injury				
– wound rupture	Exploration. Secondary suture	462		
– peritonitis	Exploratory laparotomy	461		
– abdominal abscess	Exploratory laparotomy	461		
– failure	Management	588-596		
Pelvis				
Penetrating injury				
– minor	Peritoneal lavage	109		
	Exploratory laparotomy	356		
– major	Two-step surgery:			
	1 Exploratory laparotomy	356		
	Autotransfusion	270		
	Gauze packing	365		
	Drain	368		
	Evacuation	→	2 Definitive surgery	468
– retroperitoneal hematoma	Peritoneal lavage	109		
	Evacuation?	→	Mobilize and explore colon	362, 417
Open fracture	Peritoneal lavage	109		
	Exploratory laparotomy?	356		
	Debridement	179		
	Traction	479		
	Plaster spica	475	External fixation apparatus	478
fracture bleeding	Gauze packing	477		

Region Type of injury	Light FC	Page	Heavy FC	Page
Closed fracture	Peritoneal lavage?	109		
	Sling compression	478		
	Traction	499		
	Plaster spica	475	External fixation apparatus	478
Complications to pelvic injury				
– pelvic abscess	Exploratory laparotomy. Drain	356		
– buttock abscess	Exploration	480		
– organ failure	Management	588-596		
Back				
Penetrating injury	Peritoneal lavage	109		
	Exploratory laparotomy?	307, 356		
Spinal fracture				
– stable	Debridement	312		
– unstable	Two-step surgery:			
	1 Debridement	312		
	Transport cast	311		
	Evacuation	→	2 X-ray	308, 316
			Exploration	313
			Immobilization	317
Spinal cord injury	Transport cast	311		
	Evacuation	→	Exploration	313
			Decompressive laminectomy?	309
			Dura graft?	313
Complications to spinal injury				
– spinal hematoma	Exploration	313		
	Control bleeding	317	Decompressive laminectomy?	309
– infection	Exploration. Drain	318	Decompressive laminectomy?	309
– pressure wounds	Preventive measures	318		
– bladder contracture		319		
Upper limb in general	Evaluation of major injuries	238, 484		
	Exploration of the main bones, vessels and nerves			
	– shoulder	487		
	– arm	490		
	– elbow	495		
	– forearm, wrist and hand	504		
Upper limb soft tissue injury				
– minor	Debridement. Drain	178, 180		
– major	Fasciotomy			
	– arm	491		
	– forearm	502		
	Skin flaps	255		
	Muscle flaps	200		

Upper limb vascular injury	Exploration: See above			
– minor	Ligature	188		
– major	Fasciotomy: See above			
	Ligature	188		
	or			
	Evacuation	→	Vascular reconstruction	191
Complications to vascular surgery				
– secondary bleeding	Exploration	190		
	Ligature	188		
	Amputation?	239		
– blood clot	Embolectomy	190		
Upper limb nerve injury	Exploration: See above			
	Debridement	232	Secondary reconstruction	233
Upper limb open fracture	Exploration: See above			
	Fasciotomy: See above			
	Debridement and fixation			
	– shoulder	489		
	– arm	491		
	– elbow	496		
	– forearm	505		
	– wrist and hand	506		
	Muscle flaps			
	– shoulder	491		
	– arm	491, 498		
	– elbow	498		
	– hand	256, 509		
Complications to fracture surgery				
– delayed healing	Soft tissue flaps	200, 255		
	Bone grafting	547		
	Orthosis	214		
– osteomyelitis	Sequestrectomy	551		
Upper limb open joint injury	Exploration: See above			
	Joint washing	220		
	Muscle/skin flaps			
	– shoulder	489		
	– elbow	491, 496		
	– wrist and hand	509		
Complications to joint injury				
– arthritis	Diagnostic puncture	223		
Upper limb tendon injury	Exploration. Debridement	227		
	Secondary repair	228		
hand flexors			Secondary repair	228

Region Type of injury	Light FC	Page	Heavy FC	Page
Upper limb amputations	General management	238		
	Emergency amputations			
	– arm	492		
	– elbow	499		
	– forearm	508		
	– wrist and hand	509		
	Early prosthesis training	242		
Complications to amputations				
– painful stumps	Preventive measures	243		
	Skin graft	243		
– unstable stumps	Myoplasty	242		
Lower limb in general	Evaluation of major injuries	238, 514		
	Exploration of the main bones, vessels and nerves			
	– pelvis	477, 480		
	– hip joint	474		
	– thigh	522		
	– knee	532		
	– lower leg	543		
	– foot	544		
Lower limb soft tissue injury				
– minor	Debridement. Drain.	178, 180		
– major	Fasciotomy			
	– thigh	522		
	– lower leg	540, 543		
	– foot	544		
	Skin flaps	255		
	Muscle flaps	200		
Lower limb vascular injury	Exploration: See above			
– minor	Ligature	188		
– major	Fasciotomy: See above	188, 524		
	Ligature?			
	or			
	Evacuation	→	Vascular reconstruction	191
Complications to vascular surgery				
– secondary bleeding	Exploration	190		
	Ligature	188		
	Amputation?	239		
– blood clot	Embolectomy	190		

Lower limb nerve injury	Exploration: See above			
	Debridement	232	Secondary reconstruction	232
Lower limb open fracture	Exploration: See above			
	Fasciotomy: See above			
	Debridement and fixation			
	– pelvis	468, 477		
	– hip joint	474		
	– femur, upper part	520, 524		
	– femur shaft	520, 525		
	– femur, lower part	526, 534		
	– tibia, upper part	539		
	– tibia shaft	544		
	– ankle	546		
	– calcaneus	547		
	Muscle flaps			
	– thigh	525		
	– lower leg	544		
	– foot	547		
Complications to fracture surgery				
– delayed healing	Soft tissue flaps	547		
	Osteotomy	551		
	Bone grafting	536, 547		
	Orthosis	214		
– osteomyelitis	Sequestrectomy	551		
Lower limb open joint injury	Exploration: See above			
	Joint washing	220		
	Muscle/skin flaps			
	– hip joint	202, 508		
	– knee joint	534		
	– ankle joint	547		
Complications to joint injury				
– arthritis	Diagnostic puncture	223		
Lower limb tendon injury	Exploration. Debridement	227		
	Secondary repair	228		
Lower limb amputations	General management	238		
	Emergency amputations			
	– thigh	528, 537		
	– knee joint	241		
	– lower leg	548		
	– ankle	549		
	– foot	550	Hip joint disarticulation	475
	Early prosthesis training	242		

Region Type of injury	Light FC	Page	Heavy FC	Page
Complications to amputations				
– painful stumps	Preventive measures	243		
	Skin graft	243		
– unstable stumps	Myoplasty	242		
Thermal burns	Assessment of burn wounds	557		
– 20-40% TBS	Volume therapy	559		
– more than 40% TBS	Basic life support	563		
	Evacuation	→	Basic life support	161, 563
			Early skin graft	570
			High-energy nutrition	560
– partial thickness	Debridement	568		
	Closed wound management	569		
	Open wound management	569		
	Early skin grafting	570		
– full thickness, minor	Stepwise debridement	571		
– full thickness, major			Escharectomy	570
– inhalation injury	Basic life support	558		
Complications to burns				
– scar contracture	Scar excision	251		
	Skin graft	252		
– wound infection	Management	573		
Chemical burns	Debridement	572		
Electrical burns	Prevent renal failure	572, 592		
Surgery on infected cases				
– septicemia	Management	644		
– gas gangrene	Management	580		
– necrotizing fasciitis	Management	580		

Organization of the forward clinic (FC)

In order to manage heavy casualty loads effectively there are two conditions:

- The FC must be strictly organized: The most experienced surgeon present in the FC is in charge of the clinic. Every staff member should be assigned specific duties. The discipline has to be strict.
- A written plan for the medical management must be set up for each casualty, from the battlefield up to the post-operative rehabilitation and secondary surgery.

Table 3
FC routines and responsibility

Level	Procedures	Responsible
Battlefield	First triage Basic life support Prescriptions for evacuation Fill in Injury Chart	Mobile BLS team
Evacuation	Basic life support Note in Injury Chart	BLS team member
Emergency room	Second triage Assess basic life support Emergency surgery Fill in Patient Chart	Senior surgeon Clinic BLS team
Operating room	Surgery Prescribe treatment after surgery Fill in Patient Chart	Surgeon
Bed department	Monitor vital functions Dress wounds Fill in Patient Chart	Nurse/paramedic

Injury Chart

See also Burn Case Chart: p. 566.

The chart should be simple; inside the battlefield there is no time for elaborate documentation. The chart must include facts on the weapon and range, time of injury and the BLS given before FC admission. This is one proposal for a standard injury chart:

Sarobi **Clinic**

Injury chart

Patient's name: Mohammad Khan
Address: Sarobi
Father's name: Ismahil Khan

Sex: (M) F
Age: 23
Blood type: B+

Field management

Diagnosis	Weapon: Mortar shrapnel				Time of injury: 1992 May 7, 0530 am
	Range: 15 m Site of injury: Chardewal				
	R. open femur fracture R. open tibia fracture				

Vital signs						
Respiratory rate	10-24	(25-35)	over 35	under 10	none	
Systolic BP	over 90	(70-90)	50-69	under 50	no carotid pulse	
Mental response	(normal)	confused	to sound	to pain only	none	

Field triage: T1 (T2) T3 T4

Field BLS
i.v. Ketamine 50 mg
i.v. diazepam 5 mg i.v. Pcl. 10 mega ie
Ringer 3000 ml Macrodex 1000 ml
Fracture reduction + splint

BLS starts: May 7 0630 a.m

Evacuation
Orders: i.v. Ketamine 30-60 mg each 30-60 minute
Ringer 1000 ml per hour
URGENT!
Field officer: Wares/paramedic

Evacuation starts: May 7 0700 a.m.

Clinic management

Diagnosis	Degree of injury:	Moderate	Serious	Critical	
1:	R. open femur fracture, comminut.		x		Time of admission:
2:	R. open tibia fracture, segmented	x			May 7
3:	Le. eye injury, penetrating		x		0900 a.m.

Vital signs					
Respiratory rate	(10-24)	25-35	over 35	under 10	none
Systolic BP	(over 90)	70-90	50-69	under 50	no carotid pulse
Mental response	(normal)	confused	to sound	to pain only	none

Clinic triage: T1 (T2) T3 T4

Clinic BLS
Fasciotomy R. thigh (i.v. Ketamine)
Blood (B+ cross-matched) 1000 ml
Ringer 1000 ml

BLS starts: May 7 0900 a.m.

Surgery
Orders: Explore R. femoral artery!
Debridement – fracture fixation!
Anesth: Atropin – diazepam – Ketamine!
Clinic officer: Dr. Rehan

Priority for surgery: within 2 hours

Use the Injury Chart to collect data for quality control programs: p. 700.

Mental response:
- eye opening
- speech

The Patient Chart is filled in on admission at the forward clinic and the Injury Chart stuck to it. The Patient Chart should follow each patient all the time within the clinic up to rehabilitation and secondary surgery.

Patient Chart page 1 SAROBI **Clinic**

Patient's name: MOHAMMAD KHAN
Address: SAROBI
Father's name: ISMAHIL KHAN

Sex: (M) F
Age: 23
Blood type: B+

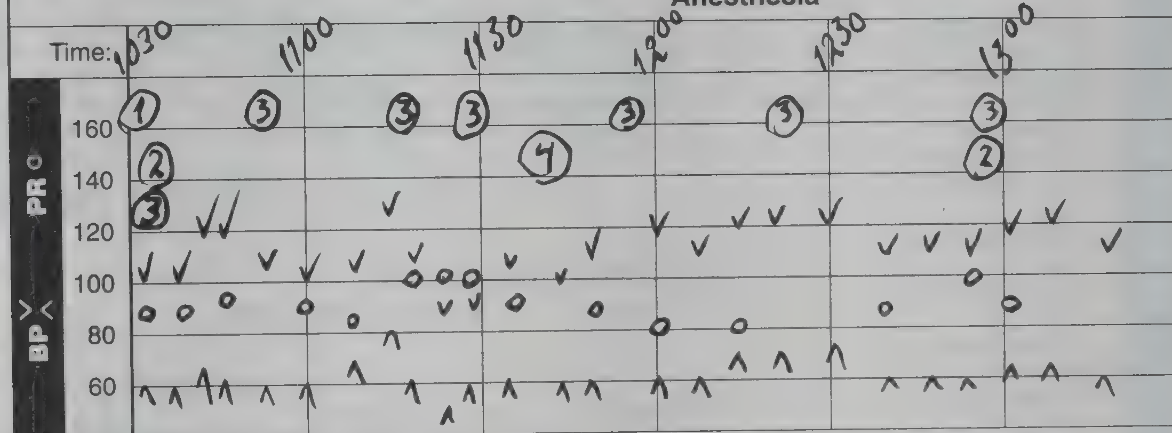
Surgery

Diagnosis and surgery — Degree of injury:	Moderate	Serious	Critical
1: Total rupture deep femoral artery R	X		
– ligature. Main femoral artery OK!			
2: Comminuted open femur fracture R		X	
– extensive debridement. Extern. fix. app			
3: Open tibia fracture – moderate debrid.	X		
– Trueta cast. The eye injury is not penetrating!			

Start surgery: May 7, 1040 a.m.

Finish surgery: 0110 p.m.

Anesthesia



Infusions: Ringer 1000 ml | Ringer 1000 ml | Ringer 1000 ml
Macrodex 500 ml
Blood (B+) 500 ml | Blood 500 ml

Drugs:
1. i.v. atropine 1 mg
2. i.v. diazepam 5 mg
3. i.v. ketamine 150 mg
4. i.v. penicillin 10 mega IU

Method: intermittent i.v. Ketamine

Complications: none, except hallucinations

Post-operative orders

Monitor specially: – circulation / temperature of R. foot!
– bleeding on drains R. thigh!

Analgesia: i.v. Ketamine 25 mg OR i.v. morphine 5-10 mg

Mobility: a

Fluid intake:

Drugs:

└ check Hb 0600 p.m. and May 8. Prepare blood (1000 ml)!
– Ringer/Glucose 3000 ml → May 8 0800 a.m. P.O. tonight!

Dressing

Where: operating room Anesthesia/analgesia: Ketamine

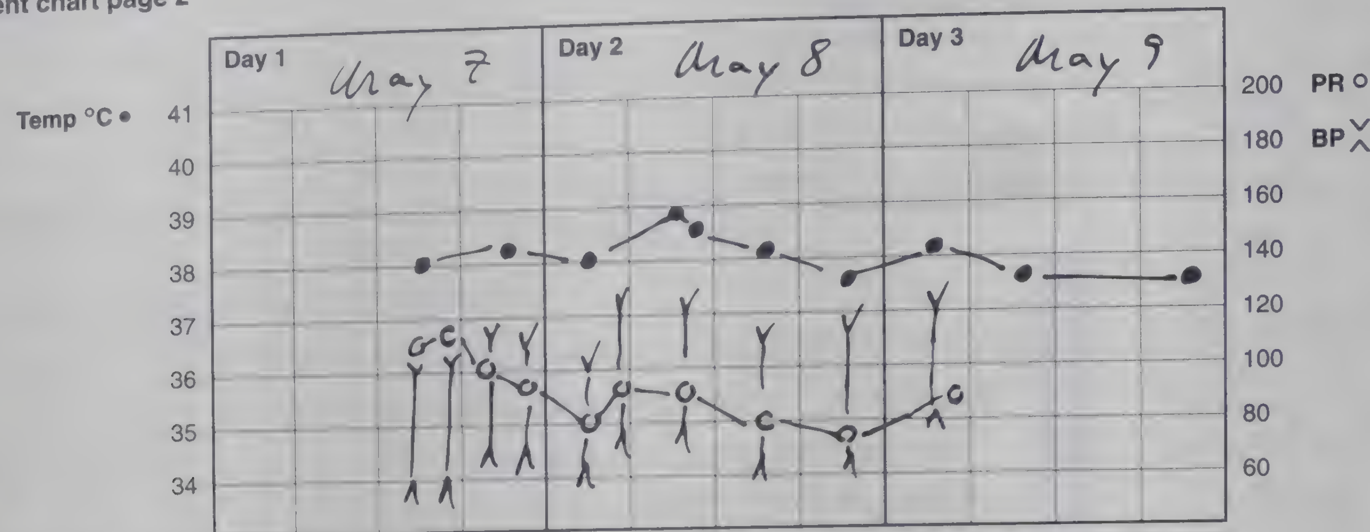
Monitor specially: viability of soft tissue flaps R. thigh

First dressing: May 11

By: surgeon

Signature surgeon: dr Hans Anesthesiologist: Dr. Aziz

Patient chart page 2



	Day 1 May 7				Day 2 May 8				Day 3 May 9			
Fluid balance												
Bleeding				300		300		150	50			50
Vomit			200									
Urine				800	1100	300	200	250	900	200	200	250
Daily loss			1000		—	2200	—		—	2000	—	
Total output			2300		—	4800	—		—	3650	—	
Per oral						300	500	500	850	600	1100	1300
Tube feeding												
Infusion			Ringer 1000 1000		Glucose 1000	Ringer 1000		1000				
Blood transf.												
Total intake			2000		—	4300			—	3850	—	
Balance			÷300			÷500				+200		
Urine per hour			— 80 —		180	50	30	60	—	65	—	
Laboratory												
Hb							9.5					
Hct					22				25			
X-ray												
Drugs												
i.v. Morphine mg				10 7.5	7.5 7.5	5		7.5 5	7.5			7.5
i.v. Diazepam mg					5			5	5			
Penicilline			4 mill		4 mill		4 mill	4 mill				
Chloramphenicol ointm.			v	v v	v	v v	v	v v	v	v v	v	v v
Dressing												
Surgery												
Comments			Circ. stable Respir. OK		much pain!		sitting in bed		unrest nightmare		out of bed	

The monitoring of cases with brain- or spinal chord injury must be close and exact both before and after surgery, otherwise complications and indications for surgery will be missed. A standard Head Injury Chart should follow all cases with cases with moderate and more than major head- and spinal injuries:

See also Glasgow Coma Scale, p. 701.

Head injury chart LA VEGA Clinic

Patients name: Maria Trujillo

Diagnosis: Open skull fracture, left temporal (sniper bullet, far range)

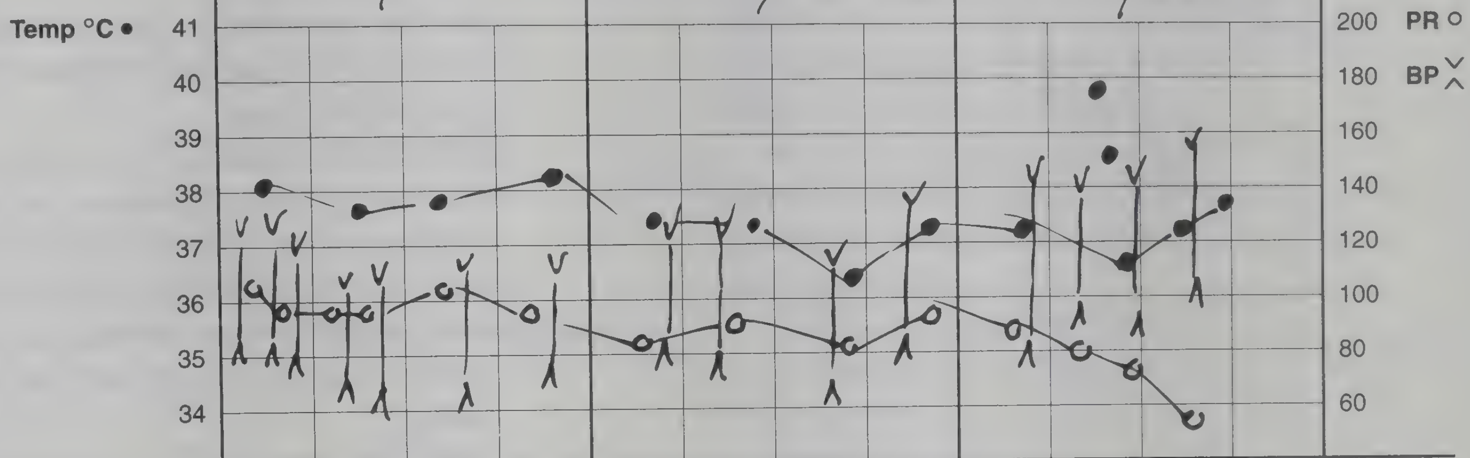
Surgery: Exploration. Debridement of brain (Ketamine i.v.)

Sex: M (F) Age: 16

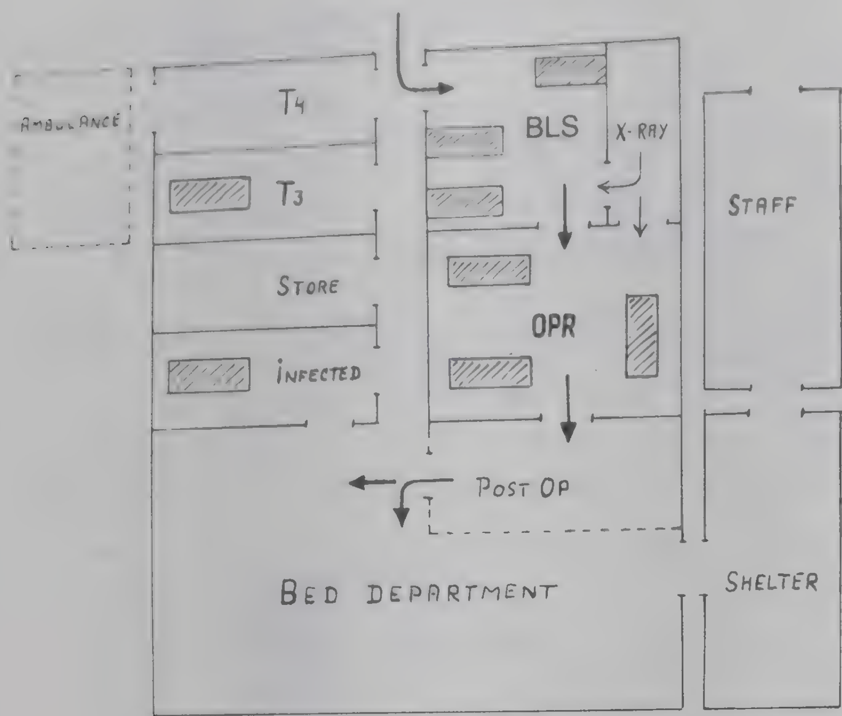
Time of injury: 6 p.m. june 10 1988

Time of surgery: 3 a.m. june 11 1988

	Day 1 june 11				Day 2 june 12				Day 3 june 13			



Normal													Mental state
Confusion			x	x	x	x	x	x					
Response sound	X	x							x				
Response pain										x x	x	X	
No response													
Right size	o	o	o	o	o	o	o	o	o	O	O		Pupils
Right response	N	N	N	N	N	N	N	N	N	↓	↓		
Left size	O	O	o	o	o	o	o	o	O	O	O		
Left response	↓	(↓)	N	N	N	N	N	↓	↓	↓↓	↓↓		
Control urine	÷		+	+		+		+	÷	÷		To OR - 8p.m. — debridement!	Motor function N (normal) W (weak) F (flaccid)
Control stools						+			÷				
Right arm	W	W	W	W	W	W	W	W	W	F	F		
Left arm	W	N	N	N	N	N	N	N	N	N	F		
Right leg	W	N	N	N	N	N	N	N	W	W	F		
Left leg	N	N	N	N	N	N	N	N	N	N	N		
Right arm			P	P	P	P	P						Sensory function N (normal) P (poor) Z (zero)
Left arm			N	N	N	N	N						
Right leg			P	P	N	N	P						
Left leg			N	N	N	N	N						
Respiratory rate			20	22	20	20	25	20	38	30	14		
Vomit								✓	✓✓	✓			
Others													



Standard structure of a heavy FC: The illustration shows one clinic building; you may apply the same plan for a tent clinic.

- BLS: Emergency department for triage and BLS. If X-ray service is available, it should be attached here.
- OPR: Operating room (T1 and T2 cases), close to the emergency department, and well protected against shrapnel and light weapons.
- T3: Unit for clean dressings and minor surgery (T3 cases).
- T4: Unit for dead and dying casualties.
- STORE: For infusions, drugs etc. Close to the emergency department.
- INFECTED: A heavy FC should have one room reserved for dressing and surgery on infected cases, completely equipped as an OPR room.
- BED DEPARTMENT: A light forward clinic may need 5 beds, a major second line clinic, 30-200.
- STAFF: Living/sleeping unit, should be close to the shelter.
- SHELTER: For staff, T3 cases and family members.
- AMBULANCE: Covered from air, close to the clinic.

Notice: As a mean, one surgical team on one operating table may manage 6-10 cases/24 hours. To avoid congestion and delay before surgery, the emergency department and the operating room in a heavy FC should each have 2-3 tables, one for each BLS and surgical team. Also the surgical capacity is increased if one section of the bed department (POST OP) is reserved for post-operative monitoring and other critically ill patients. The patients, still under anesthesia, are taken to the POST OP immediately when surgery is finished, to be monitored by experienced nurses.

Standard medical and technical equipment

The mobile one-man clinic: p. 66.

The lists below give guidelines only. With the equipment listed a light FC should be able to provide definitive surgery to 85% of all admitted cases. And the heavy FC should be able to manage all kinds of casualties. Even lighter mobile clinics (BLS and forward surgery) may be constructed combining the essentials from the light FC model below with a BLS kit. The number you need of each item can be assessed from the standard consumption lists in Tables 4 to 7 below.

Table 4
Standard equipment for a forward clinic

Light FC	Heavy FC
Infusions and drugs	
Ringer or NaCl 0.9%	Ringer or NaCl 0.9%
	Ringer lactate
Plasma expander?	Plasma expander
	Glucose 120 mg/ml 240 mg/ml
Infusion set	Infusion sets
I.v. cannulas diam 0.6 and 1.4	I.v. cannulas diam 0.6 1.0 1.4 and 1.7
	Long i.v. catheter (subclavian)
	3-way stopcock for infusion lines
	Blood transfusion bags (autotransfusion)
	Micropore filters (autotransfusion)
Inj. pentazocine 30 mg/ml	Inj. pentazocine
– morphine 10 mg/ml or buprenorphine 0.3 mg/ml	– morphine or buprenorphine
– ketamine 50 mg/ml	– ketamine 10 and 50 mg/ml
– diazepam 5 mg/ml	– diazepam
	– midazolam 1mg/ml
	– chlorpromazine 25 mg/ml
	– metoclopramide 5 mg/ml
– atropine 1 mg/ml	– atropine
– adrenaline 0.1 mg/ml	– adrenaline
	– ephedrine 50 mg/ml
	– dexamethasone 4 mg/ml
	– heparin 100 IU/ml 5000 IU/ml
Inf. metronidazole 5 mg/ml	
Inj. penicillin 5 mega IU	– penicillin
– ampicillin 2 g	– ampicillin
	– frusemide 10 mg/ml
	– mannitol 150 mg/ml
	– KCl 1 mmol/ml
	– CaCl 1 mmol/ml
	– multivitamins
– lidocaine 10 mg/ml	– lidocaine 5 mg/ml
	– lidocaine 10 mg/ml with adrenaline
	– bupivacaine 5 mg/ml
Syringes 2 ml 5 ml 10 ml	Syringes
Cannulas 0.6x25 mm	Cannulas
0.8x40 mm	
	Spinal needles
BLS equipment	
Stethoscope	Stethoscope
BP apparatus	BP apparatus
	Ophthalmoscope

Light FC

Oral airway (3 sizes)
Vacuum suction (hand/pedal)
Suction catheters 2.6-4.6 mm

Adult laryngoscope

Endotracheal tubes (set of 6)

Mouth masks (3 sizes)
Self-inflating bag

Chest tubes 8-11 mm
Naso-gastric tubes 4-7 mm
Urethral catheters (Foley) 3-6 mm

Urine bags (1.5 l) with tubing
Rubber tourniquet
Head lights, batteries 1.5V
Backpacks for BLS kits

Heavy FC

Oral airway (3 sizes)
Vacuum suction
Suction catheters
Tracheostomy tubes, 6 mm 8 mm 10 mm
Adult laryngoscope (3 blade sizes)
Pediatric laryngoscope
Endotracheal tubes
Flexible introducers
Mouth masks (3 sizes)
Self-infl.bag w.oxygen reservoir
Oxygen
Chest tubes 8-11 mm
Naso-gastric tubes 4-7 mm
Bladder catheters (Foley) 4-6 mm
Suprapubic catheters 4-6 mm
Urine bags (1.5 l) with tubing
Rubber tourniquet
Headlights
Backpacks

Surgical instruments
– the set for general surgery

1 Knife handle no 4
Knife blades no 22

1 Scissors, curved 18 cm
1 Scissors, for bandages
1 Needle holder 16 cm

1 Dissecting forceps (surgical) 18 cm

1 Dissecting forceps (anatomical) 18 cm
4 Hemostatic forceps (curved) 12.5 cm

4 Hemostatic forceps (curved) 18.5 cm
2 Retractor (sharp)

2 Bowl (stainless) 17 cm

2 Pair of sterile gloves?
2 Surgeon's mask?
2 Surgeon's cap?

Corrugated drain
Tube drain

1 Instrument tray 26x32 cm
2 Knife handle no 4
Knife blades no 15, 20 and 22
1 Scissors, curved 14.5 cm
1 Scissors, curved 18 cm
1 Scissors, for bandages
1 Needle holder 16 cm
1 Needle holder 18 cm
1 Dissecting forceps (surgical) 14 cm
1 Dissecting forceps (surgical) 18 cm
1 Dissecting forceps (anatomical) 14 cm
1 Dissecting forceps (anatomical) 18 cm
4 Hemostatic forceps (curved) 12.5 cm
4 Hemostatic forceps (curved) 14 cm
4 Hemostatic forceps (curved) 18.5 cm
2 Retractor (sharp)
2 Retractor (blunt)
2 Bowl (stainless) 17 cm
4 Towel forceps
4 Pair of sterile gloves
2 Surgeon's mask
2 Surgeon's cap
2 Surgeon's gown
Corrugated drain
Tube drain

6	Surgical drape (linen) 50x70 cm	6	Surgical drape 50x70 cm
1	Surgical drape with slit	1	Surgical drape with slit
4	**General surgical set**	**8**	**General surgical set**
	Supplement for orthopedic surgery		
1	Bone nibbler (straight)	1	Bone nibbler (straight)
		1	Bone nibbler (curved)
1	Bone wire saw (Gigli), 3 mm	1	Bone wire saw (Gigli), 3 mm
		1	Raspatorium
		1	Chisel (straight)
		1	Hammer
		2	Bone hook (sharp)
		1	Bone awl
1	Hand drill	1	Hand drill
6	Steinmann pin 2 mm	6	Steinmann pin 2 mm
6	Steinmann pin 4 mm	6	Steinmann pin 4 mm
6	Bone wire (Kirschner) 1 mm	6	Bone wire (Kirschner) 1 mm
6	Bone wire (Kirschner) 1.5 mm	6	Bone wire (Kirschner) 1.5 mm
1	Wire-cutting forceps	1	Wire-cutting forceps
		1	External fracture fixation set
1	**Set for orthopedic surgery**	**2**	**Set for orthopedic surgery**
	Supplement for chest and abdominal surgery		
		1	Knife handle no 5
		1	Needle holder 23 cm
2	Abdominal retractor (50 mm broad)	2	Abdominal retractor (50 mm broad)
1	Abdominal retractor (S-shaped)	2	Abdominal retractor (S-shaped)
		4	Artery forceps (curved) 24 cm
2	Intestinal clamp (curved, elastic)	2	Intestinal clamp (curved, elastic)
		4	Intestinal tissue forceps (10 teeth) 15.5 cm
2	Surgical drape (linen) 1.5x2 m	2	Surgical drape 1.5x2 m
1	Surgical drape (linen) 1.5x2 m with slit	1	Surgical drape 1.5x2 m with slit
1	**Set for abdominal surgery**	**2**	**Set for abdominal surgery**
	Supplement for vascular surgery		
		1	Vascular scissors (curved 60 degr.) 190 mm
		1	Artery forceps curved (Satinsky) 270 mm
		1	Artery forceps curved (Satinsky) 200 mm
		2	Artery forceps straight (De Bakey) 210 mm
		4	Artery forceps curved (bulldog) 65 mm
			Embolectomy catheter
		1	**Set for vascular surgery**

	Light FC		Heavy FC
	Supplement for skull surgery		
1	Hand drill	1	Hand drill
1	Perforator (Doyen)	1	Perforator (Doyen)
2	Burr (Doyen), small and large	2	Burr (Doyen), small and large
		1	Bone nibbler (curved)
		1	Dura elevator
		2	Dura hook
		1	Saw (Gigli)
		1	Conductor for wire saw
		1	Brain spatula
		1	Forceps for hemostatic clips (Adson)
			Hemostatic clips
1	**Set for trephination**	**1**	**Set for skull surgery**
	Supplement for skin grafting		
1	Dermatome, small (Silver)	1	Dermatome, small (Silver)
	Razor blades (for Silver)		Razor blades
		1	Dermatome (Humby)
			Blades (Humby)
1	Wooden plate (for grafts)	1	Wooden plate
2	Dissecting forceps (anatomical) 14 cm	2	Dissecting forceps (anatomical) 14 cm
	Adhesive skin closure, 6x10 mm		Adhesive skin closure
1	**Set for skin grafting**	**1**	**Set for skin grafting**
	Others		
1	Cornea scrape	1	Cornea scrape
		4	Grates (stainless) with holes (instrument sterilz.)
10	Set of five 10x20 cm gauze packs	10	Set of five 10x20 cm gauze packs
10	Set of five 30x30 cm gauze packs	10	Set of five 30x30 cm gauze packs
4	Set of six 50x70 cm surg. drape	4	Set of six 50x70 cm surg. drape
4	One 1.5x2m surgical drape	4	One 1.5x2 m surgical drape
		4	Set of two surgeon's gowns, caps and mouth masks

Suture materials (size USP)

Light FC		Heavy FC	
Dexon (Catgut)	1	Dexon/Vicryl	1
			0
	3-0 (cutting needle)		3-0 (cutting needle)
	3-0 (round needle)		3-0 (round needle)
			5-0
Ethilon (Silk)		Ethilon (Silk)	2
	1		1
	3-0 (cutting needle)		3-0 (cutting needle)
	3-0 (round needle)		3-0 (round needle)
			5-0

		Prolene	0
			4-0
			6-0
			8-0 (cutting needle)
Vessel tie mersilene (silk)	1	Vessel tie mersilene (silk)	1
	3-0		3-0
	Dexon 0		Dexon 0
	Dexon 3-0		Dexon 3-0
Suture needles	curved 3/8 cutting round	Suture needles	curved 3/8 cutting round
	curved 1/2 cutting round		curved 1/2 cutting round
	straight cutting round		straight cutting round

Dressing materials

Gauze, rolls of 100 m	Gauze, rolls of 100 m
	Tubular gauze (no 34 and 56)
	Applicator (tubular gauze) no 1
Vaseline gauze	Vaseline gauze
Elastic bandage	Elastic bandage
Adhesive tape 25 mm 50 mm	Adhesive tape 25 mm 50 mm
Cotton, rolls	Cotton, rolls
Plaster of Paris	Plaster of Paris rolls 7.5 cm
rolls 10 cm	rolls 10 cm
rolls 15 cm	rolls 15 cm
Plaster shears	Plaster shears
Plaster cast bending forceps	Plaster cast bending forceps
	Plaster cast spreader
	Plaster cast cutter (electric)
Flexible splinter frames	Flexible splinter frames
Sterilizer drums	Sterilizer drums
Formalin (conc. solution)	Formalin (conc. solution)
	Water filter and purifying equipment
Water tank	Water tank
Buckets, 10 l	Buckets, 10 l
Kettles 7.5 l	Kettles 7.5 l
	Pressure boiler 10 l
Primus heater (kerosene)	Primus heater
Wash basin (stainless) 4 l	Wash basin (stainless) 4 l
Soap	Soap
	Hydrogen peroxide solution
	Savlon (conc. solution)
Bowls (stainless) 17 cm	Bowls (stainless) 17 cm
Examination gloves (vinyl)	Examination gloves (vinyl)
Aprons (vinyl), disposable	Aprons (vinyl), disposable
Drape (vinyl), rolls	Drape (vinyl), rolls
Waste bags (plastic) 60x60 cm	Waste bags (plastic) 60x60 cm
Nail brush	Nail brush

Light FC

Surgeon's mask (disposable)

Others – medical

- Pens for marking
- Injury Charts
- Patient Charts
- Thermometers standard
- Test strip (hematuria)
- Kerosene lamp
- Kerosene
- Flashlight
- Batteries
- Plain table (surgery)
- Buckets
- Ax
- Nails
- Spades
- Rope 6 mm
- Insecticide sprayer

Others – technical

- (WHF field communication units)

Heavy FC

Surgeon's mask (disposable)

- Pens for marking
- Injury Charts
- Patient Charts
- Thermometers standard low temperature
- Test strip (hematuria)
- Blood-typing equipment
- Measure (glass), 100 ml
- Measure (stainless), 1000 ml
- Measure tape (100 cm)
- Weighing scale
- Kerosene lamp
- Kerosene
- Flashlight
- Batteries
- Operating table
- Instrument table
- Buckets
- Ax
- Nails
- Spades
- Rope 6 mm
- Insecticide sprayer
- Mosquito nets

- WHF units
- Antennae station
- El. generator 1000 W (diesel)
- Diesel
- Operation lamp
- Cautery unit
- Refrigerator (may be kerosene run)
- Electric cable
- Microscope
- Slides and cover glasses
- Spectrophotometer (Hb test)
- Cuvette micro (spectrophotom.)
- Blood lancets
- Mobile X-ray machine

X-ray film cassettes	24x30 cm
	35x35 cm
X-ray films	24x30 cm
	35x35 cm

Developer
Fix
Processing tanks
Lamp (safe light for darkroom)
Lead markers ("R" and "L")
Lead-rubber plate (for protection)
Lead apron

Protective equipment

It will increase the effectivity of the FC in general. Protection is not only a matter of staff policy, it also regards the patient's rights: Reducing the strain upon the medical staff, protective equipment will also improve the casualty management under military pressure. Protection is essential for the forward BLS teams; it should also be considered for the surgical teams.

- Protective vest with groin protector (total weight 1.5-2.2 kg) provides effective protection against medium- and far-range gunshots and shrapnel.
- Standard gas mask gives protection against moderately potent chemical warfare agents.
- Camouflage nets for tents and ambulances.
- A wall of sandbags 50 cm thick around tents/buildings provides protection against everything except center hits and chemical warfare.
- The walls of a truck operating theater or truck clinic are made out of double 4 mm steel plates with a sheet of fine sand between them.

The technical items

Military considerations/mobility and the availability of electricity set the technical standard of the clinic.

Without electricity: You can manage well with two headlamps, in a cool store four 1.5 V batteries provide sufficient light for four hours of surgery; a portable pedal suction with a capacity of 1 liter; sterilization in pressure boiler/kettle on a kerosene heater; a simple microscope with a mirror and handlight/sunlight as light source (blood tests); reliable refrigerators running on kerosene are available (blood bank).

With electricity the standard of the clinic may be set at a higher level. A diesel electric generator of size 145 cc - 400 cc will provide 1200 W - 4200 W over 5-6 hrs from 1 liter of diesel. That is enough to carry several technical facilities in a minor clinic. The main costs of maintenance are filters for air, oil and fuel. A cautery unit will increase the surgical capacity and safety. The unit consumes 250 W/hour. Rules of maintenance and use must be strictly adhered to in order to prevent serious electric injury to patient and staff. The capacity of a mobile X-ray apparatus depends mainly on the skill of the X-ray technician. Film processing may be manual, but for good quality the water must be filtered and the temperature of processing solutions is max.18°C. Both capacity and quality are increased by a small desk-top processor, capacity 1 film per minute, electric consumption 500 W/hour. In a clinic with heavy casualty load, an instrument washing machine and a small autoclave may have first priority.

Light and heavy BLS kits

A 20-kg BLS backpack is developed by the authors for casualty management in jungle warfare. For information, address Hans Husum.

Tempo is important in basic life support. The drugs and instruments should be properly packed in order to be ready without delay in any emergency situation: The bags and connections must fit the different tubes and cannulas; the instruments must be clean and well protected during rough field use; the materials should be packed in standardized bags easy to carry by hand or as backpack. The actual composition of BLS kits and the number of each item depend upon the staff skill and the casualty rate expected. Below are listed proposals estimated for management of five casualties, the evacuation time from the site of injury to the FC being maximum four hours.

Table 5
Light BLS kit

Airway	1	Stethoscope
	1	Oral airway size 1
	1	Oral airway size 2
	1	Oral airway size 3
Breathing	1	Mouth mask, infant
	1	Mouth mask, child
	1	Mouth mask, adult
	1	Self-inflating bag
	2	Naso-gastric tube
Circulation	1	Rubber tourniquet
	5	I.v. cannulas, diam 0.6
	5	I.v. cannulas, diam 1.0
	5	I.v. cannulas, diam 1.4
	5	I.v. cannulas, diam 1.7
	5	Infusion sets
	6	Lactated Ringer infusion, 1000 ml
	3	Plasma expander infusion, 500 ml
	2	Adhesive tape
	10	Gauze packs, 10x10 cm
	10	Gauze packs, 20x20 cm
	2	Gauze packs, 40x40 cm
	5	Elastic bandage, 10 cm
	1	Scissors
Drugs	1	Inj. ketamine 50 mg/ml, 10 ml
	5	– pentazocine 30 mg/ml, 1.5 ml
	5	– diazepam 5mg/ml, 2ml
	2	– lidocaine 1% with adrenaline, 20 ml
	5	– penicillin 5 mega I.E.
	5	– ampicillin 3 g
	2	Inf. metronidazole 5 mg/ml, 100 ml

	5	Syringes, 2 ml
	5	Syringes, 5 ml
	10	Cannulas 0.6x25 mm
	10	Cannulas 0.8x40 mm
Others	1	Headlight
	5	Injury Charts
	2	Splinter frames (for fractures)

Table 6
Heavy BLS kit

	1	**Light BLS kit AND:**
Airway	1	Vacuum suction (hand/pedal)
	6	Suction catheters, 3-5 mm
	1	Adult laryngoscope (3 blade sizes)
	1	Pediatric laryngoscope
	1	Set of endotracheal tubes (set of 6)
	1	Syringe (tube cuff)
	2	Flexible introducers (for endotracheal tubes)
Breathing	1	Chest tube, 8 mm
	1	Chest tube, 11 mm
	2	Forceps (for chest tube)
Circulation	1	Venous cut-down set
	1	I.v. infusion pressure bag
	5	3-way stopcock for infusion lines
	1	BP apparatus
	1	Cannula for intraosseous infusion
Drugs	3	Inj. ketamine 50 mg/ml, 10 ml
	3	Inj. morphine 10 mg/ml, 1 ml
	or	
	3	Inj. buprenorphine 0.3 mg/ml, 1 ml
	3	Inj. metoclopramide 5 mg/ml, 2 ml
	2	Inj. midazolam 1mg/ml, 5 ml
	2	Inj. chlorpromazine 25 mg/ml, 2 ml
	2	Inj. dexamethasone 4 mg/ml, 1 ml
	2	Inj. frusemide 10 mg/ml, 4 ml
Emergency surgery		See below: The one-man mobile clinic

The one-man mobile FC

When the evacuation of casualties from the battlefield to the FC lasts more than eight hours, even the best forward basic life support cannot prevent the loss of lives and limbs during the evacuation. The mortality rate and the risk of complications are reduced when the field BLS teams are trained and equipped to make the primary surgery in some village or forward camp close to the site of injury. After primary surgery (Table 2 p. 41) the patient is transferred to some nearby village or tent camp. His family, the local village people or the village health worker are instructed in the details of monitoring and nursing. The one-man FC surgeon will see to the patient 3-5 days after surgery and do the first dressing. When stable, the patient is then transferred to the clinic for further management.

The network clinic in Afghanistan: p. 28.

Equipment needed

A complete one-man clinic backpack is designed by the authors. For information, address Hans Husum.

The BLS kit and surgical instruments may be carried by one man in a well-designed backpack, total weight 15-20 kg. To the heavy BLS kit (Table 5) is added:

- **One debridement set:** Scalpel, surgical scissors, dissecting forceps (surgical), 6 hemostatic forceps, needle holder, vessel tie and suture materials. The size of instruments should allow emergency laparotomy and thoracotomy.
- **Orthopedic instruments**: Gigli saw (wire saw) for amputations; plaster of Paris (rolls 15 cm) for Trueta plaster casts; Kirschner wire (2 mm) for external fixation; Steinmann pins (4 mm) for traction management.
- **Drugs and infusions:** Either increase the amount in the backpack, or arrange small depots in local villages or camps.
- **Equipment for sterilization:** It may be included in the backpack, or borrowed from the local population.

The one-man clinic in function

This is minimum level surgery and you have to improvise. One assistant is selected among the local population to manage the anesthesia. Instruct him well in the triple maneuver to secure free airway before you start the anesthesia. When the patient is under anesthesia you may introduce an oral airway. Use intermittent i.v. ketamine anesthesia with a fixed volume of ketamine to be given at preset time intervals. Or arrange a continuous ketamine-drip anesthesia. Also select one assistant for the surgery. Instruct him on the need to keep everything sterile, and not to touch anything without your explicit permission. His main function is to provide manual retraction in the wound.

Sterilization is done by boiling instruments for 20 minutes, or you may disinfect them by formalin bath or flaming with alcohol. Surgery may be done without gloves (wash with soap for 10 minutes; consider the risk of blood-borne diseases). Regarding instruments, further improvisations may be necessary (see p. 70).

Consumption of medical materials

The consumption depends upon several factors and cannot be exactly assessed beforehand. Some factors will increase the consumption of the BLS teams and at the FC:

- Air-to-ground attacks
- Urban warfare
- Extensive mining
- Good field communication and rapid evacuation from the combat area (reduced early mortality)
- Malnutrition and endemic diseases in the operative area
- Increased skill of the FC staff

The consumption of drugs and medical items further depends upon the quality of the clinic management and the turnover of in-patients. Particularly chronic cases with protracted infections create a burden on both staff and consumption. Early primary surgery, high quality wound-care, high-energy nutrition after surgery are all factors that may increase the patient turnover and reduce the overall consumption of materials. The FC turnover is also increased and consumption reduced when rehabilitation centers are integrated in the network (the Tripoli model, p. 30) or the local popular support is utilized (the Afghan model, p. 28). FCs operating in areas of famine, malnutrition and endemic diseases should expect an increased consumption of materials.

Based upon statistics from recent regional wars we can list approximately the frequency of the main surgical procedures:

Table 7
Mean distribution of FC surgical operations (conventional warfare)

Type of surgery	% of total surgery
Minor debridements	50
Major debridements	10
Chest drainage	10
Laparotomy	5-10
Amputations	5-10
Thoracotomy	less than 5
Vascular surgery	less than 5
Skull surgery	less than 5

From Tables 5, 6, and 7 we can make a rough assessment of the medical materials needed for an FC responsible for both definitive primary and secondary surgery:

Table 8
Mean FC consumption of medical materials for 100 war casualties (battlefield BLS teams included)

Item	Unit	Number of units
Infusions		
Inf. Ringer or NaCl 0.9%	1000 ml	250
– plasma expander	500 ml	25
– glucose 120 mg/ml	1000 ml	10
– glucose 240 mg/ml	500 ml	10
– metronidazole 5 mg/ml	100 ml	10
Infusion sets	150	
I.v. cannulas 0.6 mm	10	
I.v. cannulas 0.6 mm	30	
I.v. cannulas 0.6 mm	30	
Drugs		
Inj. morphine 10 mg/ml	1 ml	50
– pentazocine 30 mg/ml	1 ml	50
– ketamine 50 mg/ml	10 ml	20
– diazepam 5 mg/ml	2 ml	50
– atropine 1mg/ml	1 ml	20
– metoclopramide 5mg/ml	2 ml	30
– penicillin 5 mega IU	1 vial	300
– ampicillin 2 g	1 vial	150
– lidocaine 10 mg/ml	20 ml	15
– bupivacaine 5 mg/ml	20 ml	15
Syringe (disposable)	2 ml	400
Syringe	5 ml	200
BLS and dressing materials		
Suction catheter	20	
Urethral catheter (Foley)	20	
Urine bag	20	
Chest tube	10	
Gauze 100 m	1 roll	5
Elastic bandage	1 roll	200
Plaster of Paris 10 cm	1 roll	30
Plaster of Paris 15 cm	1 roll	30
Drain, corrugated	1 sheet	3
Drain, tube	1 m	10
Savlon (conc.)	5 l	5
Drape (vinyl) disposable 100 m	1 roll	3
Examination glove (vinyl) disposable	1 pair	250
Apron (vinyl) disposable	100	
Surgeon's mask (disposable)	100	

Nutrition

High-energy nutrients (fat) for 10 cases for 10 days		
Feeding tubes		10

Others

Batteries (1.5 V)		150
Kerosene	10 l	3
Water		1200 l

Cleaning and maintenance of instruments

To maintain proper sterility and disinfection under field conditions is difficult. Even more so is maintenance of instrument quality in extremely hot or cold, extremely humid or dry climate. One staff member should be specifically responsible for that task.

Surgical instruments

Disinfection and sterilization: p. 656.

Most surgical instruments are made of stainless steel (18% chromium, 8% nickel, 2-4% molybdenum, 18-8-SMO) hardened to Rockwell C 35 or 60 degrees. Stainless steel instruments have a special surface polish protecting them against corrosion; if that polish is damaged, corrosion starts. Some instruments are made of carbon steel (Rockwell C 55-65 degrees) with a nickel-chromium surface polish protecting them against corrosion. Still, they are prone to corrosion after some time of use. Damaged surface polish on one instrument may cause corrosion on other instruments during sterilization.

Cleaning: Old blood and debris will prevent effective sterilization. Clean immediately after use: First wash them in cold water without soap to remove blood and proteins. Then brush them thoroughly with warm water and soap, rinse with water and dry them well. Leave scissors and forceps open during drying. Instruments used on infected cases are kept in a disinfectant solution for one hour before drying and resterilization.

Maintenance: Surgical instruments in use should be oiled every second day (weapon oil or special fat-less instrument oil) and dust-free stored. In hot, moist areas, instruments not in use should be vacuum-packed in plastic to prevent corrosion. Check the instruments before each sterilization. Check the surface polish and adjust screws. Blunt knives, chisels and scissors are sharpened with a fine well-oiled grind-stone. Never use grind-steel for surgical instruments. One main problem is surgeons using vascular clamps upon clothes and tubes, surgical scissors upon gauze and sutures, and chisels as screwdrivers; better tell them how to behave!

Sterilization: The instruments must be clean and dry before sterilization starts. Remove oil and fat with alcohol. Do not close scissors, forceps etc. during sterilization; the steam must have access to all parts of all instruments. Wrap sharp instruments in paper, gauze or thin cloth to protect them from damage. The drape wrapped around sets of instruments must be dry before sterilization starts, as moisture will prevent the steam from penetrating the

cloth. **Notice:** Moist heat/steam makes sharp instruments and needles blunt; either maintain them by intermittent grinding or sterilize them by dry heat or chemical sterilization.

Packing of surgical sets: Preferably one stainless steel grate with holes is used for each set of instruments. Using double sheets of drape (cloth or paper), wrap the crate. Mark the set: Contents and date of sterilization.

Rubber and plastic equipment

Tubes, catheters, gloves etc. are washed in cold water immediately after use, then in warm water with soap, rinsed with water and properly dried. Rubber will adhere and become damaged if stored in a moist state. Gloves are tested by blowing them; holes are then closed by patches from the inside. Before storage and sterilization, gloves are powdered with talc. Rubber and plastic deteriorate after repeated sterilizations. Do not use steam temperatures above 120 degr.C.

How to improvise

High quality standard surgical instruments are of course preferable to improvisations: The maintenance is simple, the sterilization is safe and their design is the result of years of surgical craftsmanship. However, good home-made copies of stainless steel with nickel-chromium surface polish can be made at a local mechanic's workshop. As the degree of metal hardening for the copies should be at least Rockwell C 35, soft metal alloys are not fit for surgical instruments. Handles of plastic are preferable to wood for reasons of cleaning and sterility. Under field emergency conditions, ordinary tools from the carpenter, tailor or mechanic may be used. Listed below are some improvisations that work. The list does not pretend to be complete. Our intention is to encourage the surgeon not to be dogmatic when he lacks instruments:

- **Emergency laryngotomy** is done (even without anesthesia) in the combat area with any sharp knife at hand. The assistant's finger retracts the wound edges and secures passage of air.
- **Chest tubes** are made out of a plastic water tube of appropriate diameter. The tube must be stiff enough not to collapse in the chest wall. The tube end is trimmed by scissors and some side holes are made.
- **Instead of chest tube suction:** After insertion the tube end is fixed underwater in a bottle of soap solution, analgesia is given and the patient instructed to blow child's balloons or surgeon's gloves. The positive respiratory pressure inflates his lungs and promotes chest drainage.
- **The best large-bore venous catheters** for high volume infusions are made out of the standard sterile infusion set tube (p. 146). The tube fits most saphenous veins (ankle cut-down), the cephalic vein in male adults (elbow cut-down) and femoral veins in children (groin cut-down).
- **Carpenter's tools:** Ordinary awl and drill are used to make a hole for tibia traction. The traction pin is a thick welding rod inserted by careful blows with a hammer. Corks are applied against the skin at the rod ends and plain

ropes tied to sandbags for traction. For olecranon traction (arm fractures) and trochanter traction (pelvic acetabular fractures) carpenter's eye screws may be used; they may create some local irritation of the tissues, but for 4-6 weeks they may be safely used. Ordinary burrs (8-12 mm) on a carpenter's drill may be used for trephination, but take care not to penetrate dura; the inner table of the skull bone is removed by nibbling.

- **Emergency guillotine amputation** to free a trapped patient can be done with an ordinary but sharp stainless steel knife. A carpenter's saw, a sharp chisel or a straight gouge work well to set off the bone. As an alternative small-caliber drill-holes are made in the bone at close intervals at the level of amputation, and the bone fractured transversely by manual force. Or a track is made in the outer cortex around the entire circumference of the bone by light hammer blows upon the knife, and the bone can be broken by manual force. A cloth is used as soft tissue retractor.
- **Dermatome:** A scalpel blade, or better, a razor blade upon a needle holder or a barber's knife can take skin grafts of any thickness.
- **Retractors:** Nice skin hooks can be made from bent hypodermic cannulas or metal rods.

Home-made retractors
Stiff metal rods are formed into retractors, 3 mm rods for minor surgery, heavier rods for major wounds.

Standard retractors, sharp and blunt, can be made on order by any mechanical workshop.

- **Wound drains:** In the absence of soft plastic tubes any piece of rubber (bicycle tube), cloth/canvas or synthetic rope can be used as a drain after fasciotomy and debridement.
- **Instead of gauze packs:** Packs with good suction capacity are made of cloth/linen, not tightly woven, wrapped around a core of cotton.
- **Suture materials:** Threads of natural silk or linen/flax are excellent for sutures and ligatures. They may be soaked in sterile water before use, or waxed for better flexibility. Small-caliber nylon fishing cord may be used as well. Cotton threads are not fit as suture material. Tailor's needles can be used for sutures, round needles in soft tissues, cutting needles (triangular sharpened leather needles) for fascia, tendons etc.
- **Inside the abdomen:** Incisions and resections can be done with any sharp knife and scissors. Anastomosis is done by silk sutures on a straight fine-caliber round needle. The temporary colostomy is arranged over a plastic or stiff rubber rod. As the patient is evacuated further for definitive surgery, a sheet of canvas or an infusion bag may be sutured over the midline incision to relieve that incision; or it is adapted and sutured into major defects of the abdominal wall as a temporary graft (p. 359). Copper or soft steel wires tied around wooden rods may also be used as tension-relieving sutures (p. 370).
- **Major orthopedic instruments:** The models available on the market are expensive. Local copies of skull traction devices (halo, cervical traction tongs) may be made. Particular notice should be paid to the alloy used for cortical screws and nails; they must be made of hardened steel (minimum

Rockwell C 35). Apparatus for external fixation is of particular importance in the management of major open fractures; simplified copies of the standard models may be made, particularly the ball joint brackets and couplings may be simplified. But again the materials used in the transfixing bone pins must be of high quality to avoid excessive local irritation of the tissues.

Make your own instruments!
High quality surgical instruments are expensive, and the cheap copies on the market are of poor quality, many of them not at all fit for surgery. Better buy some essential instruments of high quality, and include an experienced mechanic with an equipped workshop in a major field medical network. First, his maintenance of instruments and skills in improvisation reduce the running costs of your network. Second, his planning and production of high quality instrument copies in peaceful times help you avoid hurried and poor improvisations during wartime management.

Section 2

Basics of war surgery

Points to note – Chapter 3

The main question in all wartime injury management: How much energy is released from the bullet inside the patient's body?
- study the projection of stones in water to find out what is energy output: p. 76
- different types of bullets make different wound tracks. Know the reasons why why the bullet loses speed: p. 79
- some case studies of thigh wound tracks: p. 517

Blast injury – the injury that leaves no wounds
- study how pressure waves can cause damage: p. 82
- note the early clinical signs of pressure wave injuries: p. 83

The mine injury – several injuries in one
- tissues above the amputation level are often damaged: p. 85
- there are particular problems with the anterior lower leg compartment in mine amputations: p. 540
- do not miss pelvic and abdominal mine shrapnel injuries: p. 85 and 468
- there may be abdominal pressure wave injuries as well: p. 83

War surgeons should be interested in weapon technology
- local wars are used to test new weapons. Study their effect carefully to improve the surgical treatment
- report the use and effect of new types of weapons and ammunition to the authors

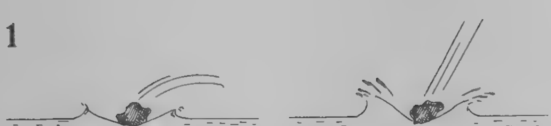
3 Physics of the weapon

Weapon theory

> The term "projectile" used in the theoretical discussions in this chapter denotes any kind of bullet, shrapnel, stone/debris or other projectiles that do not carry a secondary explosive. Illustrations of wound tracks caused by bullets correspond to wounds from any minor projectile.

How extensive is the internal injury? The question is essential in any war casualty, and more so under field conditions without X-ray service. Your answer will determine the classification by triage, the type of anesthesia to use, positioning of the patient on the operation table, the kind of instruments you need, the incisions you choose etc. The extent of tissue damage depends on the energy output from the actual projectile. So, as a wartime surgeon, in each case you have the obligation to collect the facts necessary to estimate the energy output of the projectile that hit your patient.

1



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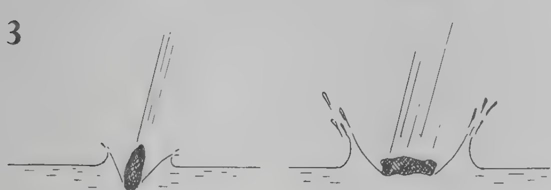


What is energy output?

1 The speed affects energy output: A stone carefully put into the water makes small waves. That same stone thrown forcefully into the water makes big waves. The bigger waves have more strength; they contain more energy.

2 The weight affects energy output: A small stone thrown into the water makes small waves. A big stone thrown into the water makes big waves.

3 The retardation affects energy output: An oval-shaped stone makes small waves. A flat-shaped stone makes big waves because the resistance between the water and the stone is increased; its velocity is rapidly reduced; it is retarded more.

> A projectile in flight carries an amount of (kinetic) energy, **Ep**, determined by the law:
>
> $$\mathbf{Ep = 0.5 \times M \times V^2}$$
>
> where M is the weight (mass) of the projectile and V is the velocity of the projectile.

Thus the energy carried by any projectile is mainly determined by its velocity: Increasing the velocity twice causes a four-time increase in its energy; increasing it three times causes a nine-time increase in its energy. The general trend in military arms production has been a steady increase in projectile velocity. However, the "best" projectile, the projectile with the highest capacity to kill ("stopping power", "knock-down power", "probable kill rate") should also be able to transform most of its energy to tissue damage inside the body. The main

question is therefore not how much energy was carried by the projectile, but **how much of this energy was released within the body of your patient:**

> **The law of energy output:**
>
> $$\mathbf{E = 0.5 \times M \times (V1^2 - V2^2)}$$
>
> where V1 is the velocity of the projectile at the inlet wound and V2 is the speed of the projectile through the outlet wound.
>
> The projectile that creates most damage inside the body has a high hit velocity (V1) and a low outlet velocity (V2). At best it does not leave the body at all, that is, V2 is zero.

Before the physical examination of the patient, collect exact information on the actual weapon:

Evaluate the inlet velocity!

- What kind of weapon was used? You should collect information about the weapons commonly used in your area, and their projectile velocity. Regarding rifles you should know which ammunition they may carry.
- What kind of ammunition was used? The general trends in modern assault rifles and antipersonnel fragmentation weapons are reduction of projectile weight and increase in projectile velocity. And to use unstable projectiles (ill. 6-10 below).
- What was the range of the hit? Due to air resistance a low-weight projectile will lose velocity during flight more rapidly than a heavy one. Thus the range of the hit (from the muzzle of the rifle, from the site of explosion of a grenade) affects the inlet velocity, especially so in modern fragmentation weapons.
- How are the flight stability and penetration of that projectile? A low-weight projectile tends to become unstable during flight; uncontrolled tumbling will reduce its accuracy. So there is a lower limit of assault rifle projectile weight, even if calibers 4.85 mm and 4.6 mm are now ready for production (p. 80). A heavy projectile has better penetration in flight. In sniper hits and during jungle fighting you should still expect to find the traditional 7.62 mm projectile and heavy projectiles such as the .303 in (the Lee-Enfield Jungle carabine) and .30 in (US Garand) with a high-inlet velocity even at wide range hits. Even heavier bullets are known to be in use (p. 80). In pistols light ammunition (less than 9 mm) is unstable in flight and of poor combat value due to the low muzzle velocity of pistol bullets.

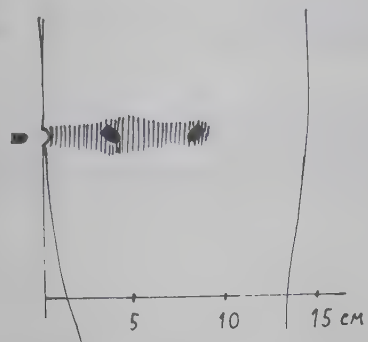
Evaluate the outlet velocity!

You have to study the outlet wound carefully, as modern and improved projectiles tend to stop inside the body (V2=zero), as projectiles may fragment inside the body, as the wound track is seldom a straight one, and as multiple hits in one patient are common.

- Are you sure it really is an outlet wound and not another inlet wound? Battle rifles that fire clusters of three and three bullets are common. Rifles with extremely rapid three-shot clusters (2000 rounds/min.) are under production.
- How extensive is the outlet wound? If it is wide with extensive tissue damage close to the outlet surface, the projectile has left the body with considerable velocity; you can hope for less internal damage. Multiple small outlet wounds indicate a projectile that fragmented inside the body; the internal damage is probably wide.

From a small outlet wound you cannot draw any conclusions; the internal damage may be extensive, or it may be small (p. 517).

4



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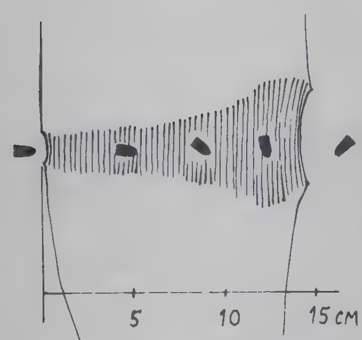


4 **The typical low-velocity wound track** (9 mm pistol bullet, close range thigh hit with inlet velocity 450 m/s) is generally narrow. The energy output from the projectile is poor due to moderate inlet velocity. You should expect to find necrotic tissues not more than 2-3 cm from the penetration line of the projectile. The outlet wound, if any, will be small.

5 **The typical high-velocity wound track** (7.62 mm assault rifle bullet, close range thigh hit with inlet velocity 900 m/s) is generally wide. The energy output from the projectile is about four times that of a pistol bullet. It produces a shock wave in the tissues making a cavity which expands and immediately collapses behind the projectile. That **cavitation effect** is typical for high-velocity projectiles and causes tissue necrosis 10 cm or more from the line of projectile penetration. The vacuum created by the cavitation sucks cloth, dirt and bacteria from the skin into the wound track.

The wound track

Much is written on how surgeons should manage wounds from modern "high-velocity weapons". However, the muzzle velocity of a rifle or the inlet velocity of any projectile is not the most important factor to consider. The inlet velocity only determines the maximum amount of energy that **may** cause tissue damage.

Table 1
Muzzle energy of common rifle bullets

Ammunition	5.45x39	5.56x45	7.62x51	7.62x54 R
Bullet weight	3.42 g	4.0 g	9.3 g	9.65 g
Muzzle velocity	900 m/s	915 m/s	840 m/s	850 m/s
Muzzle energy	1.4 kJ	1.7 kJ	3.2 kJ	3.9 kJ

From the operating table we know that the 5.45 mm (M16 rifle) and the 5.56 mm ammunition (the AK-74 rifle) cause far more damage to the tissues than do most heavier ammunitions even if the total energy carried by the lighter bullets are far less, as this table illustrates. The reason is that different types of bullets behave differently after hitting the body. The main factor for surgeons

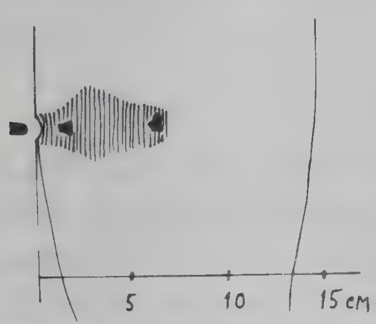
to consider is not potential energy but how, where and how much of this energy is actually released within the wound track. And that is a question on how the projectile is retarded inside the human body.

> **Projectile retardation → energy release → cavitation → tissue destruction**
>
> When retardation is maximal, the cavitation is also maximal. The most effective projectile causes maximum cavitation close to or within vital structures, that is 5-10 cm inside the inlet wound. Each kind of rifle ammunition has its particular cavitation effect and particular wound track, its "fingerprint". The wartime surgeon has a lesson to learn from veteran fighters: To know the "fingerprints" of common ammunition will make both triage and surgical performances better.

Wound tracks of common rifle ammunitions: p. 517 and 518.

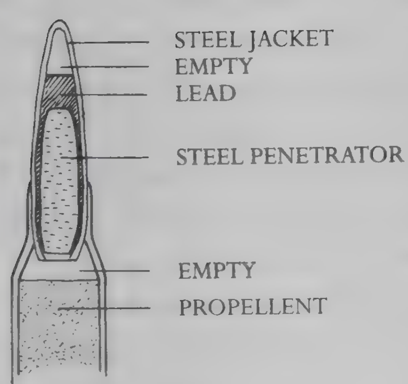
We will study factors that determine the cavitation effect. The principles here illustrated by bullets are valid for any kind of high-velocity projectiles, fragmentation grenades and bombs, cluster bombs etc.

6



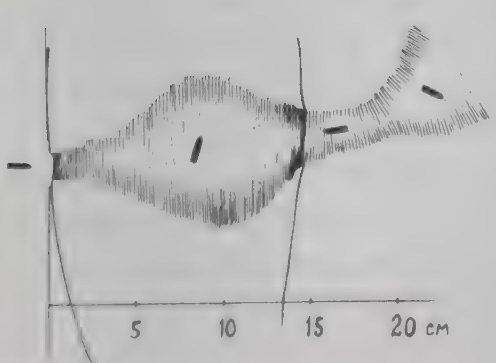
6 **Deformation causes retardation:** the thigh wound track of a .357 Magnum soft nose pistol bullet. The lead nose of the bullet is deformed even by soft structures such as skin and subcutaneous tissue. The retardation is maximal just inside the inlet wound, and this is where you find most extensive necrosis. Compare with the effect of a standard hard nose pistol bullet in ill 4. Another way to deform bullets is to cut their nose, forming so called "hollow-pointed" ammunition. In high-velocity rifle bullets this is an effective method to move the point of maximum cavitation from 25 cm down to 10-15 cm after the inlet wound. Consequently the mortality rate is increased.

7



7, 8 **Destabilization causes retardation:** the 5.45 mm ammunition for AK-74, the latest and most effective assault rifle from the former Soviet countries. What is particular about this bullet is the air-filled space in its nose. On hitting the target, the heavy lead-antimony core is pushed forwards; the bullet becomes very unstable and starts rotating inside the wound track. In a thigh hit this causes a maximum cavitation close to the femur, the main nerves and vessels. Among the standard rifle ammunitions the destructive effect of the AK-74 is matched only by the new model 5.56 mm ammunition for the US rifle M16 (p. 518). In fact, when the first AK-74 rifle injuries were seen in the Afghanistan war, one wondered whether the projectile was a chemical one; the tissue damage was so much greater compared to the well-known 7.62 mm AK-47 bullet injuries.

8



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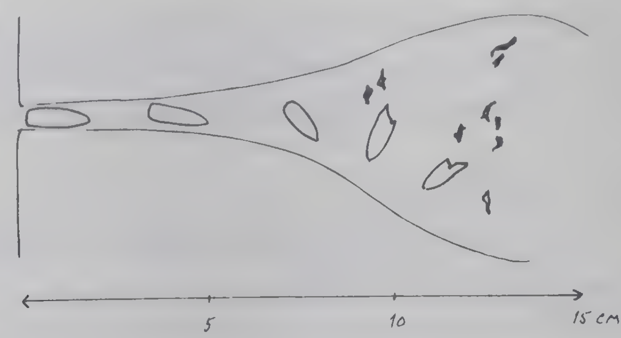

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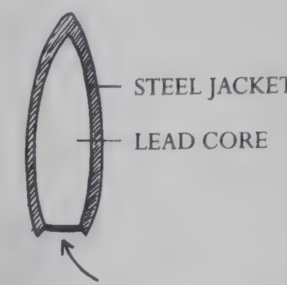
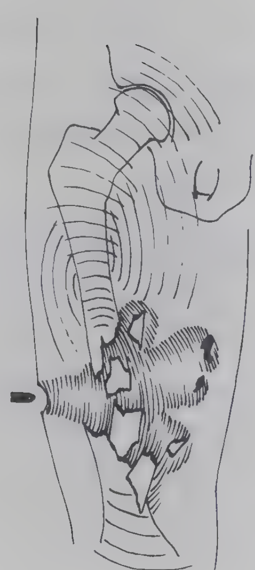


9, 10 Fragmentation causes retardation: the 5.56 mm bullet for the US M16 rifle (A1, old model). The cupro-nickel jacket is open at its base and lead core fragments are thrown out when rotation starts, thus deforming the jacket and increasing the cavitation. Other light-jacketed bullets will also expand inside the wound track with a fragmentation pattern as that of the M16 bullet (ill 39.3).

11



11 Bone hit causes retardation: Hitting bone, most bullets become deformed or broken into fragments, and you will find the main cavitation on the outlet side of the fracture. Also bone fragments are accelerated into the tissue as secondary projectiles, adding to the cavitation. Energy shock waves may also travel along the bone, into structures close to the bone. Also remote organs may be damaged.

Most rifle ammunition are not standardized regarding their stability. Variations of 30% are common. Within one and the same round one bullet may become unstable 8 cm inside the wound track, another bullet 16 cm inside the wound track. The first bullet may cause serious limb injury, the second one will probably not.

New trends in rifle ammunition

According to the International Hague Convention, "dum-dum" bullets are prohibited in warfare. The soft nose, hollow-point and expanding rifle bullets discussed above are all modern "dum-dum" bullets. As real life warfare is never conducted under humane and fair conditions, the surgeon should prepare himself to handle even more sophisticated projectile injuries in the future.

Low-caliber, unstable bullets: The standard assault rifle ammunition of the 1990s will be the 5.45 mm (Soviet) and 5.56 mm (Israel – Galil, France – MAS, US – M16, Belgium – FN). The 7.62 mm is on its way out in infantry fighting. The low-caliber bullets are more rapid and less stable within the target; their destructive capacity is higher. "Pencil projectiles" for rifles are under trial (4.6 mm Heckler and Koch, 5.56 mm "Individual Weapon" of UK). The long and thin pencil-like bullets, with muzzle velocity well above 1000 m/s, are stable in flight but extremely unstable within the target.

Increased effective range: Optical sights (day-and-night both-eye sights) as standard equipment on assault rifles give better accuracy and increased lethality, particularly at ranges more than 300 m. Also laser sights for rifles are under production. For these weapons heavy sniper bullets are developed with improved stability and less loss of flight velocity. Sniper bullets of 16 g are effective at ranges well above 1000 m. Also flechette rifle bullets are very accurate in long-range fighting. The flechettes do not rotate during flight as do standard rifle bullets. Flechettes are stabilized by steering fins and lose less velocity in air. They penetrate deeply into the body, but their wound track is narrow.

Cluster fire: Some rifles may fire clusters of three and three bullets. Those rifles are very rapid, and in close-range fighting they may cause three wound tracks close to each other with a delay of 0.03 seconds between each hit. Also submachine shotguns of caliber 12 with 15 rounds and optical/laser sight have

been developed for close-range fighting. The propellant of the shotgun ammunition is improved to make it effective up to 100 m. The cavitation of traditional shotgun hits is massive close to the inlet wound, but the penetration is poor. With the improved ammunition the weapon will be extremely lethal.

How do the tissues tolerate cavitation?

Every tissue has its particular features that also affect the wound track:

- Skin is elastic and absorbs the cavitation well. It is stretched and returns to normal without much necrosis.
- The subcutaneous fatty tissue is less elastic and has poor blood supply. Cavitation causes extensive necrosis due to destruction of small vessels.
- Muscle tissue is even less elastic and will not absorb the cavitation. Muscle cells are directly crushed by the pressure wave. Also minor vessels are torn causing secondary hypoxia and muscle cell death.
- Bone is not elastic at all (except in small children). Compound fractures are common even if the projectile does not hit the bone directly. And the energy wave may travel along the bone and cause extensive necrosis in muscle bellies and compartments close to the bone. The bone may also carry the energy wave across joints into remote organs (p. 80).

Tangential hits

In a wound track close to the body surface the energy wave will expand more in the direction of least tissue resistance, that is towards the surface. The energy wave is less and so is the cavitation towards the deep structures. Consider this in debridements of tangential injuries: Most important is the debridement of the superficial part of the wound track. You may split the entire roof of the track, and do a limited debridement of the floor of the track only.

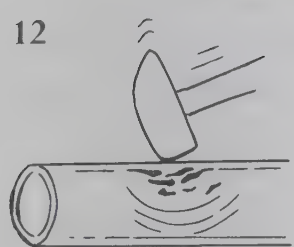
Blast injuries

The blast is a detonation of high-explosives (HE) in bombs, rockets, shells, grenades or mines. The blast forms a high positive pressure wave moving at 3000 m/s in all directions from the point of detonation, as waves from a stone hitting water. The pressure of the blast wave may reach 20 kg/square cm, that is equivalent to 40 000 kg towards the trunk of a man (modern fuel-air explosion bombs). Air absorbs the blast wave well, and it is rapidly reduced with increasing range from the detonation point. Inside closed spaces the pressure wave is not absorbed, and even minor blasts (blast hand grenades of 250 g HE) may cause considerable internal damage. There are three types of blast injuries:

- **Fragment injuries:** The blast weapons are not designed to produce antipersonnel fragments, but they spread high-velocity (primary) fragments from their case in an irregular pattern. Also stones and debris are accelerated by the blast into high-velocity secondary fragments. The fragment injuries may be serious, but the hit probability is low.
- **Crush injuries:** People are thrown to the ground or against objects. In city warfare the majority of blast cases are people trapped or buried under broken buildings.

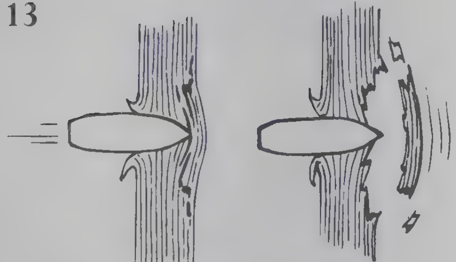
- **Pressure wave injuries:** Fragment and crush injuries have obvious clinical signs and cannot be missed. But the specific pressure injuries are silent injuries: Close to the blast site, people may develop signs of serious respiratory distress and/or intra-abdominal injury after an interval of 48 hours without symptoms. Not a few of these patients die in our hands despite intensive medical support. There are two physical effects by which the pressure wave creates these silent injuries: **a spalling effect** inside organs when the pressure wave is reflected and **an implosion-explosion effect** when the pressure wave enters air-filled spaces of the body.

12



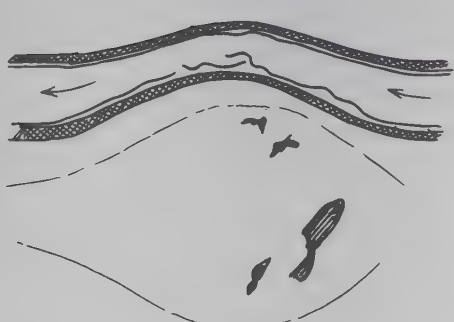
12 Spalling effect of pressure waves: When you hit a rust-eaten iron tube from the outside with a hammer, rust flakes will detach from inside the tube. This is called the spalling effect of pressure waves. When the wave enters a less dense medium from a dense one, the pressure wave is reflected. The reflection will compress and destroy the structures exactly at the point of reflection.

13



13 Spalling effect of penetrating projectiles: Not only blast weapons may cause injury by spalling. Spalling is also utilized in some projectiles designed to penetrate armor or reinforced concrete (antishelter projectiles). The actual projectile does not need to completely penetrate the armor/wall. A partial penetration may still cause detachment of internal fragments or an entire disc due to the spalling effect. In spaced armor or concrete, the air spaces absorb the spalling effect making the projectile less effective.

14



15

14, 15 Spalling effect inside the wound track: Exactly at the point where the pressure wave enters a less dense tissue, the tissue damage will be extensive. The inner lining of the vessel, the intima, will be torn off the main vascular wall and be further rolled off by the bloodstream. Thrombosis develops at the narrow part of the vessel. Intimal injuries are common; the pressure wave may rise from a blast weapon or, in this case, from the cavitation of a rifle bullet hit.

Most blast pressure injuries are caused by a combined effect of spalling and implosion. The structures at risk are air-filled spaces and organs composed of loose connective tissues (spleen, fat, retroperitoneal tissues). The common injuries are the following:

Blast pressure lung injury

Due to the implosion effect alveolar walls are broken, fluid collects in damaged lung tissue and increasing lung edema may develop. The implosion effect inside the abdominal cavity lifts the diaphragm and causes damage to the inferior parts of the lungs. The physical signs are increasing respiratory distress with rapid and shallow respiration and coughing of blood-stained mucus. Symptoms develop slowly and often after a free interval of 6-48 hours. Lung X-ray may show patchy infiltration 24-48 hours after the injury.
The management consists of:

- Bed rest, half-sitting position, and observation for 48 hours for all patients at risk. Physical activity may provoke symptoms.
- Unrest and anxiety is common; intermittent diazepam i.v.

- Steroids i.v. may be of effect if given within three hours after the injury.
- Diuretics in high dose may have some effect in moderate cases.
- Generally the condition is resistant to medical therapy and serious cases are often fatal.

Blast pressure abdominal injury

Entering the abdominal cavity the pressure wave will increase as an explosion. So also when it further enters the lumen of stomach and intestines, particularly in the colon. Depending on the size of the pressure wave a variety of symptoms may develop. In moderate cases slight bleeding and edema in the stomach and intestinal mucosa are common. Moderate cases will have few or no bowel sounds, some tenderness on palpation and often blood with the stools. Surgery is not indicated, but should be done if you suspect peritonitis. Serious cases may develop circulatory shock soon after the blast due to profuse intestinal bleeding, tears of the spleen or liver. Or they develop late signs of slowly progressive peritonitis due to contamination through multiple minor ruptures in the intestines.

The management consists of:

- 48 hours n.p.o. and close monitoring of all risk cases.
- Peritoneal lavage.
- Laparotomy is done on suspicion; several negative laparotomies are better than missing one intestinal rupture.

Blast pressure air embolism

Through the torn alveolar septa, air bubbles enter the blood circulation from the lungs and reach the heart coronary circulation or central nervous system. Air embolism may give rise to a variety of symptoms: general unrest and confusion; circulatory failure and falling blood pressure; total circulatory collapse; sudden death if vital centers in the brain or medulla are put out of function. The diagnosis is confirmed by fine-needle artery puncture: bubbles of air with the blood. The management consists of supportive therapy depending on which organ is affected.

Blast pressure rupture of the eardrum

The sign is acute deafness in one ear. The diagnosis is confirmed by otoscopy. Without infection the rupture will heal spontaneously. The eardrum rupture is important as an indicator of risk cases.

> Blast pressure injuries have few early clinical signs. The diagnosis is often missed. For all possible blast cases:
>
> - Collect exact information on their distance from the blast site.
> - General unrest and eardrum rupture indicate that serious complications may follow.
> - Observe all blast cases for a minimum of 48 hours.

Mine injuries

Antipersonnel mines carry 30-300 g high-explosives. There are two main types:

- **The fragmentation mine** is located on a rod overground, or it jumps from ground level up to 1-2 m before explosion. It is released mechanically by wires or by computer control. Fragmentation mines are often inter-connected in series of 3-6 mines to increase the fragment concentration. Fragment velocity is more than 1000 m/s.
- **The blast mine** is buried in the ground or scattered on the surface by air or artillery. It is released by direct pressure (foot, vehicle). The injury is caused mainly by the blast pressure wave. Also irregular fragments from the mine case and secondary fragments (stones, debris) add to the injury.

The traditional mines are defensive weapons, cheap, easy to produce and effective. This has made AP mines popular in regional wars, and wide areas are mined without proper mine-mapping. Injuries on civilians and soldiers are common from both enemy and "friendly" mines. Non-detonated artillery grenades and cluster bomblets add to the problem. Due to modern technology, mines are no longer only a defensive weapon. In wars to come mines will have also an offensive mission, and the rate of mine casualties will increase. AP mines and antitank mines are now scattered by planes, rockets and artillery. Each individual mine or the whole minefield may have remote control, either computerized or by operator as a response to surveillance. Offensive minefields may be extinguished by self-sterilization, remote sterilization or air-fuel blast bombs. The AP fragmentation mines are also improved: Better explosives and case design have increased the fragment velocity, and lethal range is well above 50 m. Needle fragments further increase the AP effect.

Mine injuries are combined injuries

The typical mine amputation casualty has often associated injuries. Approximately one third of mine injuries are caused by manipulation of mines, children's play, clearing of minefields and spontaneous explosion of old unstable mines; any regional injury may arise. Major AP mines may also cause blast wave injuries to the trunk. All mine casualties should thus be closely examined for several possible injuries:

- **Limb amputation:** The diagnosis cannot be missed. A 30 g mine may amputate at the ankle level. A 150 g mine may amputate through the thigh.
- **Blast wave injury:** In particular the abdominal cavity is at risk. Also monitor respiration. Chest X-ray 24-48 hours after the injury may show patchy lung infiltrations.

Management of blast wave injuries: p. 82.

- **Perineal injury:** Fragments may damage the male organs. Profuse bleeding is controlled by compression.
- **Pelvic injury:** Minor high-velocity fragments may penetrate deeply and cause damage to pelvic organs (rectum, small intestine, bladder) with internal bleeding and peritonitis. This may in fact be the main injury, but easy to miss when combined with a dramatic limb amputation.
- **Head and eye injury:** Penetrating fragment injuries may be seen in one of three cases, also combined with lower limb amputations.

Management of mine amputations

The mine limb amputation is an extremely high-energy injury. The mine amputation thus has particular features different from amputations caused by major shrapnel, entrapments etc. The extent of soft tissue injury is often underestimated by the surgeon; infection, delayed healing and repeated amputations being the result.

- **Early basic life support:** Mines continue to kill when the war is over. Civilian casualties damaged by accident often come late for surgery. Amputations caused by minor mines seldom bleed much, but cases with high amputations or double amputations are often admitted in circulatory shock. The risk of early and late complications is reduced when village people in mined areas are instructed in the main procedures of mine-casualty basic life support: proper control of bleeding; volume therapy; early antibiotics in high doses; respiratory support and analgesia during the evacuation. Depots of plasma expander and i.v. fluids should be arranged in strategic villages.
- **No tourniquet, but compressive dressing:** Tourniquets are seldom effective. In most cases they cause venous stasis without obstructing the main arteries. This adds to the problem of compartment syndrome commonly seen in mine amputations. Compressive dressing on an elevated limb (elastic bandage or rubber bands) controls any amputation bleeding, and reduces the compartment edema.
- **Emergency fasciotomy:** As a rule the energy wave running along the limb causes muscle necrosis and vascular damage above the amputation level. If the evacuation to the clinic will take more than one hour, fasciotomy should be done at the site of injury. Most important is decompression of the deep flexor compartments of the foot (below ankle amputations), of the lateral lower leg compartment (below knee amputations), of the flexor compartments of the hand (finger and hand amputations) and of the forearm extensor compartments (below elbow amputations).
- **X-ray above the amputation level – secondary fragments:** Stone, dirt, clothes and minor bone fragments may be pressed deep into the intramuscular spaces by the blast wave. They become the focus for infection unless removed, but are difficult to identify by surgical exploration alone. Soft tissue X-ray before surgery helps identify the areas to be explored.
- **Explore above the amputation level – two step surgery:** The high-energy blast wave is conducted along the bones above the traumatic amputation level, in particular along the long bones of the lower leg and forearm. As a routine the muscle bellies close to the long bones should be explored through wide exploratory incisions. Non-bleeding muscles are excised and arteries explored for intimal injury. If you are in doubt regarding the soft tissue viability, leave the incisions open and re-explore after 24 hours.
- **The lateral lower leg compartment – a particular problem:** The lower leg amputation is the most common mine injury. In particular missed injury of the lateral compartment is a common cause of thrombotic complications, late infection and sepsis. In missed diagnosis and cases late for surgery you often find the lateral compartment muscles pale with soft consistency, whereas the posterior compartments are well circulated. Particular anatomic features account for this problem: The lateral compartment is narrow with very tight walls. Even moderate muscle edema causes a considerable rise in com-

The lower leg compartment problem: p. 540.

partment pressure. Adding to the problem is the particular vulnerability of the anterior tibial artery: The point where the artery enters the compartment through the interosseous membrane is a common site of intimal injury. The artery should be explored during primary surgery and ligated above the level of injury if damaged. If the artery and compartment injury is extensive, mid-leg amputation with long posterior flap or forward rotation of calf muscles should be considered. Antithrombotic therapy should start on admission.

Modern arms and ammunition

There are two main types of ammunition. One type is discussed above (eg. rifle ammunition). It has a propellant charge and the projectile does not carry any secondary explosives; the destructive capacity depends on the kinetic energy of the projectile only. The other main type has two separate charges, one propellant driving the projectile and one high-explosive (HE) carried by the projectile causing the target damage. Modern HE projectiles may cause a wide spectrum of injuries. They also set certain limits on how, where and when we are able to organize our war medical network.

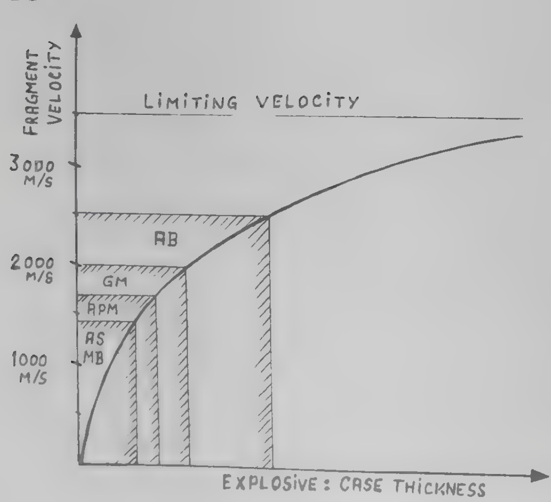
Fragment energy and fragment distribution

The propellant charge driving the projectile **burns** with a speed of 500 m/s. The HE charge **detonates** with a speed 2000-9000 m/s. After the Vietnam war HE ammunition was improved; aluminium added to the explosive charge increased the explosive energy considerably. A "post-Vietnam generation" of antipersonnel (AP) fragmentation weapons was developed with higher fragment velocity and a total destructive capacity far beyond that of the "old" generation. Also propellants were improved, giving better accuracy and fragment distribution.

Table 2
Approximate weight of fragments (in g)

From AP hand grenade	0.1-0.3
From fragmentation cluster bomblet	1-2
From flechette cluster bomblet	0.5-8
From AP mine	0.7-1
From light artillery shell	5
From heavy artillery shell	13

16



16 Fragment velocities: The fragment velocity increases when the relation explosive/case thickness increases. With the HE in use at present there are upper limits for fragment velocity. R=rifle bullet. AS=artillery shell. MB=traditional mortar bomb. APM=antipersonnel mine. GP=guided projectiles (mortar, rocket). AB=aircraft bomb.

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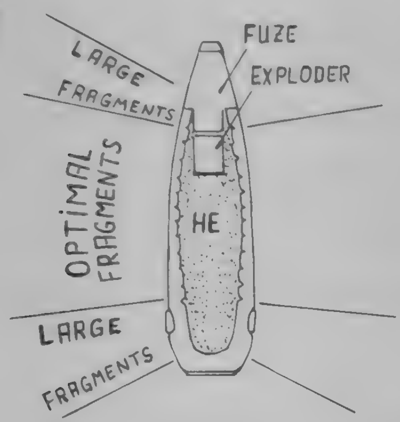

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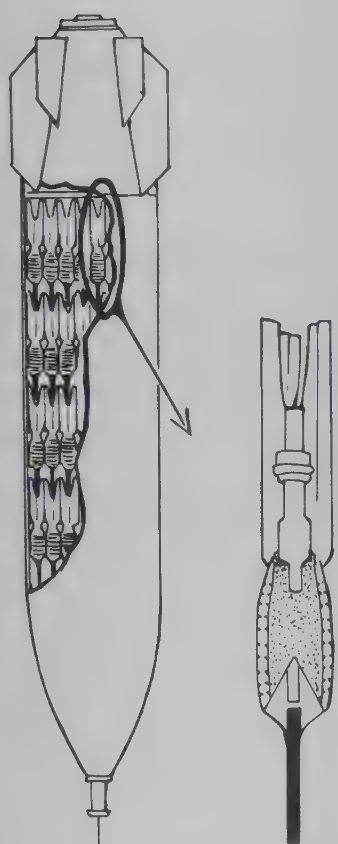


17 Fragment distribution: During the 1980s fragment distribution from shells, mortar bombs, grenades and rockets was greatly improved. In these modern artillery shells, the sides are pre-notched on the inside to produce standardized fragments with optimal distribution. Or the projectile case consists of pre-formed fragments (eg. 10 mm steel balls) embedded in plastic. A burst height of 2-4 m produces the best AP fragment effect (see below, smart bomblet, rod-nose bombs, jumping mines).

18 Cluster weapons: One major carrier projectile (here an airplane bomb) contains several (from 3 to 1000) bomblets (clusters). Each bomblet has its own initiation system. Cluster weapons are launched by cannons or mortars, or as rockets and airplane bombs. The clusters may be AP fragmentation bomblets, armor penetrating bomblets, AP mines, incendiary etc. International conventions and law banned the use of cluster weapons against civilian targets, but due to their effectiveness they are a common and effective offensive weapon against major cities as well as village areas. Cluster weapons can provide saturation fire on a wide ground area better than any other non-chemical weapon. The light fragments (1-2 g) lose much velocity with increasing range, but this is compensated for by a high incidence of persons with multiple injuries within the ground cover area. Thus modern cluster weapons are said to be tactical equivalents of short-range nuclear weapons. The Chilean cluster bomb here illustrated will cover a ground area of 50 000 square meters with high-velocity AP fragments. The 250 clusters, each of 800 g, are dispersed from the carrier in the air; the nose cone charge of one cluster may penetrate 15 cm steel, and the pre-fragmented cluster body produces a "cloud" of AP fragments.

Instead of the traditional, small but irregular steel fragments from anti-personnel fragmentation weapons, flechettes will be common in the future. A US flechette warhead under trial contains 1200 flechettes of 60 grains (1 grain =0.0648 g); two warheads detonated simultaneously will form a flying high-velocity cylinder 1500 square meters wide. Flechettes are relatively stable and do not lose much velocity during flight. They are also stable after the hit, and can penetrate deeply with a narrow wound track. Their main effect will be an increased rate of multiple-injury casualties.

Cannons

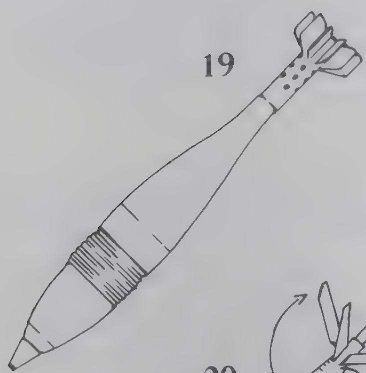
The common HE artillery shell is illustrated above. Cannons (from 40 mm and upwards) may also take cluster grenades; one 203 mm cluster grenade may contain 180 AP fragmentation bomblets and cover a ground area of 60 000 square meters. With modern rocket-assisted projectiles the effective range of heavy artillery is increased up to 90 km. Rapid fire rate (15-20 rounds/min) causes saturation fire on one target area. Steerable artillery projectiles are on the way, laser-guided shells from 70 to 155 mm are already in production. Combined with laser target designating systems (below) the future accuracy of cannon fire will be far better.

Mortars

They have so far been a rather simple means of local fire support for infantry in close fighting. The destructive capacity, range and accuracy have been moderate.

Lately mortar ammunition has been improved with thinner cases with more and stronger HE. The result is fragment velocity above 1500 m/s, effective fragment distribution and far better hit probability. Better propellants and rocket-assisted mortar bombs have increased the range up to 20 km (240 mm). In the future, cluster fragmentation ammunition will be the common mortar ammunition. One single mortar round may cover a ground area of 4000 square meters. Also for mortars, laser-guided missiles are under trial; in tests they have proved a target accuracy of 0.5 m.

19



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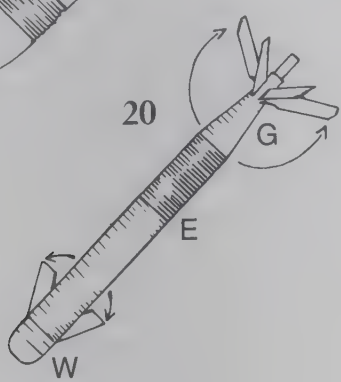


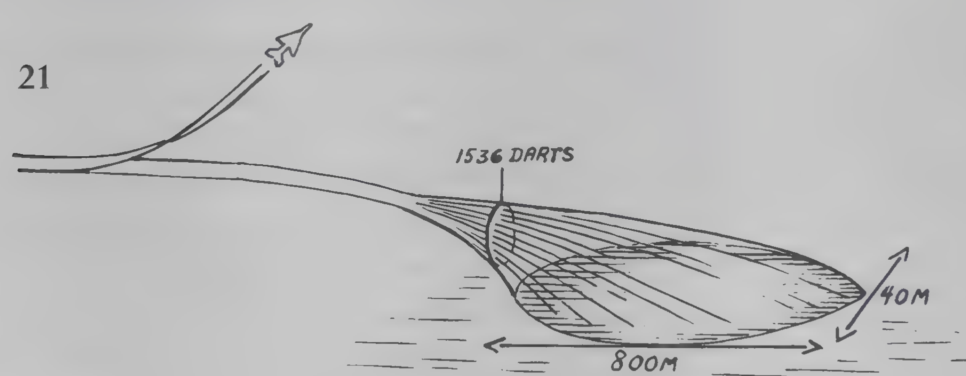
19 The traditional mortar bomb (Soviet 120 mm HE fragmentation projectile, 3.9 kg TNT).

20 The laser-guided mortar projectile (UK, Merlin). G=guidance section. E= electronic instruments. W=warhead.

Rockets (short and medium range)

Ground-to-ground and air-to-ground rockets may carry any kind of warhead – chemical, AP fragmentation, AP clusters, antishelter, anti-armor, incendiary etc. The traditional GTG rockets vary from 40 to 350 mm with a range from 5 to 90 km. Improved rocket launchers may fire forty rockets within six seconds. Despite heavy saturation fire, the hit probability has been low so far. For the future cluster projectiles will be common. One 120 mm cluster rocket covers 1000 square meters with AP fragments. Forty rounds of a 325 mm will saturate 60 000 square meters with AP fragments.

21



21 Multi-dart ATG rockets: This French concept is a modification of the cluster rockets. One 100 mm carrier rocket contains 192 darts of 50 g each. The plane may fire eight rockets within seconds, and the darts are released during flight and form a flying cylinder that covers a ground area of 32 000 square meters. Unguided rocket projectiles will be rare in the future. Laser-guided and heat-seeking projectiles with far better accuracy are already common, even in minor local wars.

Hand grenades

With the modern improved HE and stronger (pre-notched) steel case, the hand grenades have also increased their deadliness. There are on sale grenades that produce a combination of steel and glassfiber fragments, making X-ray fragment identification difficult. Modern offensive grenades with 250-1000 fragments, fragment velocity 2000 m/s, are lethal up to 50 m radius.

Aircraft bombs

They are of two main kinds: **The fragmentation type** of bombs has been improved in many ways. Better HE has increased fragment velocity up to 2400 m/s. Fragments from a French 190-kg AP cluster may thus penetrate 17 mm armored steel 50 m from detonation point. There are also double-charged bombs particularly designed to break shelter: the first charge breaking the concrete, the second charge being of the AP fragmentation type. And there are fragmentation bombs (Israeli) with both heavy (armor penetrating) and light (AP) fragments in one bomb. Also AP fragment distribution is improved by rod-nose bombs detonating 1-2 m above ground. One should thus expect increasing numbers of patients with more than one serious penetrating injury among future aircraft bomb casualties. Till now, the accuracy of aircraft bombs has been poor, with less than 25% of unguided bombs expected to find their target. Accuracy is improved in two ways. First, retarded bombs (parachute bombs) may be released from low-flying jet fighters (15 m above ground). Second, "smart bombs" with a day-and-night hit rate of 90% are in production. These are laser, heat-seeking or optical TV-guided bombs of the glide type with a range up to 45 km. However, evidence from the US-Iraqi Gulf war suggests an actual accuracy far less than previously claimed. Also cluster bombs are under production with target-seeking clusters.

The other main type of conventional bombs is of **the blast type**, weight from 250-2000 kg. The new generation of blast bombs are double-charged bombs of the fuel-air type. Their first charge disperses high-explosive fuel into the air 5-10 m above ground; the second main charge ignites the fuel-air mist causing an extreme over-pressure blast wave. The antipersonnel effect of fuel-air bombs is considerable; they are also used in clearing of minefields.

Future trends

Trials are done with QAZ munition (Quazi Alloy of Zirconium), AP artillery grenades with fragments coated with zirconium, a burning agent that reacts with water as well as CO_2 found in air. Penetrating QAZ fragment burns can thus be controlled by mechanical means only, not with water or any fluid. In most advanced armies night vision devices are standard on all weapon systems. Combined with better ground surveillance, this makes night-fighting as effective as day-fighting. Ground surveillance radars may identify moving persons at ranges from 50 m to 40 km. Autopilot drone surveillance planes may transmit TV pictures day and night from the battlefield. Obviously these innovations make forward medical service difficult. The main future improvement will probably be in the high-tech computer field. Countries like Israel, Taiwan and Japan have developed computerized fire control systems: The targets for fire are identified and also designated/"marked" with laser systems. The target information is given to the laser-guided projectile. In combination with exact range-finders and satellite-positioning systems, the first-round hit probability will be high. The computer systems also allow rapid adjustment of misfire.

Better weapons make things difficult

With increasing effectiveness of modern arms one can expect an increasing rate of serious injuries (triage type T1) in the battlefield and in civilian mass casualties. Even more than now, very forward surgical service is imperative to save lives and limbs. On the other hand improved weapons make forward service more difficult. In order to maintain reasonable security for medical officers, forward units must be light and highly mobile. The key factor will be training of paramedics to work independently and perform life-saving surgery in forward field positions.

Points to note – Chapter 4

Wound edema delays healing

- study the reasons why edema forms: p. 94-96
- know the procedures that reduce wound edema: p. 176
- study "the compartment syndrome" – why it happens: p. 521
  And how to prevent it by fasciotomy: p. 177

When losing blood, the body protects its vital organs

- note the three stages of circulatory shock: p. 97
- learn to assess from clinical signs how much blood is lost: p. 107
- children are different: p. 108 and 261

In grave circulatory shock, even vital organs may fail

- know the signs of kidney failure: p. 584 and 591
- know the signs of heart failure: p. 584 and 590

Painkilling is an important part of basic life support

- note the side effects of pain: p. 98
- learn how to use pentazocine, morphine and ketamine for i.v. analgesia: p. 151

Good and early basic life support reduces the risk of developing multi-organ failure

- know how to discriminate post-operative pneumonia from ARDS: p. 584 and 588
- note the signs of multi-organ failure: p. 595
- early high-energy enteral feeding reduces the risk of multi-organ failure: p. 97 and 596
- recognize the injuries and complications that increase the risk of multi-organ failure: p. 98

4 Physiology of the injury

The tissue response to injury

Burns cause specific tissue response, different from other injuries: p. 556.

Body tissues are composed of a variety of cells. Each cell is like a complicated chemical factory. In order to understand how tissues respond to injury, you have to understand how the cell reacts when it is under stress; when a crushed cell tries to survive; or when a healthy cell is working under shortage of fuel, that is, under hypoxemia and hypoglycemia. Let us first look at the normal basic cell functions. We choose a limb muscle cell as an example.

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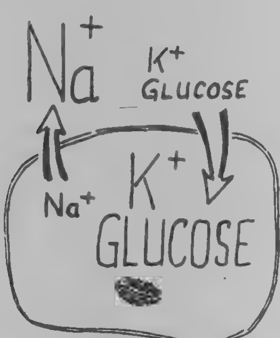
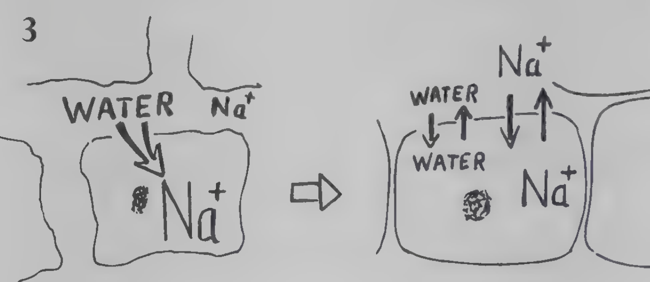


1 **Energy consumption:** Oxygen and glucose are the fuel of cells, brought from the lungs and liver, through the arterial capillaries, across the cell membrane and into the cell. Energy for the cell is produced by chemical reactions inside the cell. Carbon dioxide and waste products from the chemical reactions are carried across the cell membrane, into the venous capillaries and further to the lungs, liver and kidneys for excretion.

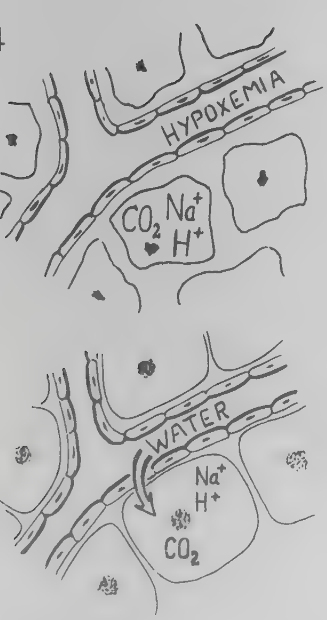
2 **Regulation by the cell membrane pump:** A chemical pump inside the cell membrane regulates the concentration of sodium, potassium and hydrogen inside and outside the cell. Also other chemical substrates needed for cell function are pumped in/out by the membrane pump.

3



3 **Regulation by osmotic pressure:** The cell needs water and produces water. The water volume inside the cell is regulated by passive osmotic pressure: Water is sucked into the cell when the concentration of sodium increases inside the cell. Therefore the cell will swell, and the salt inside the cell becomes diluted to the normal level.

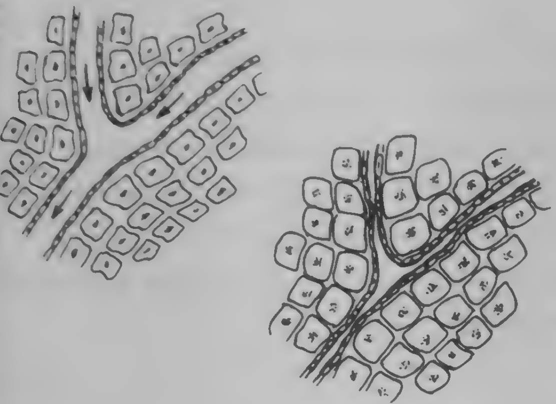
4



The response to hypoxia (shortage of oxygen): Edema

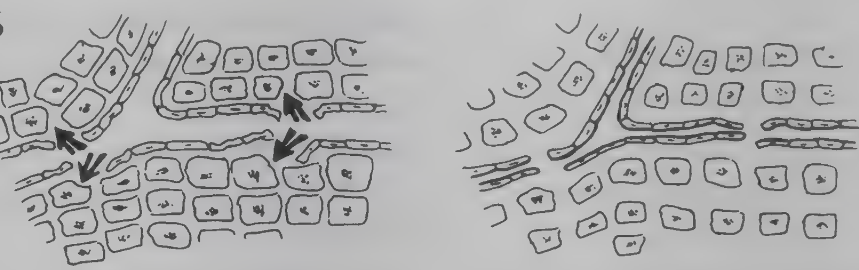
4 **Tissue hypoxia causes tissue edema:** When the muscle is hit by a bullet, arteries are damaged and less blood reaches the muscle cell. Also due to pain during the evacuation respiration is less efficient, and the blood oxygen tension reduced. This is the response of the cell: The energy production of the cell decreases due to lack of oxygen. The membrane pump slows down because of this lack of energy. Less sodium is pumped out of the cell and the levels of sodium and substrate increase inside the cell. Thus the cell becomes hyperosmolar (more concentrated salt-water solution) and water is sucked into the cell from the blood. The cell becomes swollen → cellular edema.

5



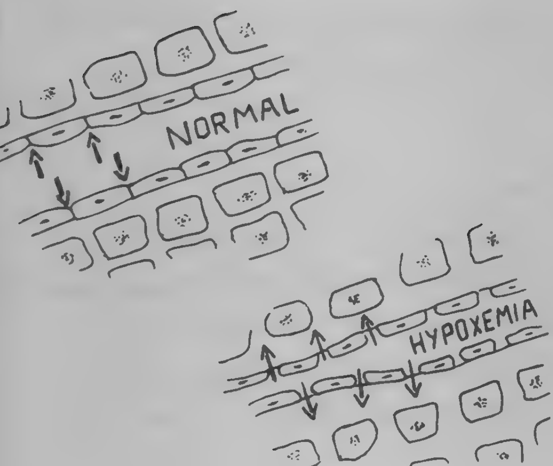
5 Vascular obstruction causes edema: Also the neighboring cells swell and the small veins become obstructed. The venous drainage becomes poor; fluid collects in the tissues and accelerates the general swelling. Gradually the edema also obstructs the arteries, and the blood oxygen supply to the cell is further reduced → increasing cellular edema.

6



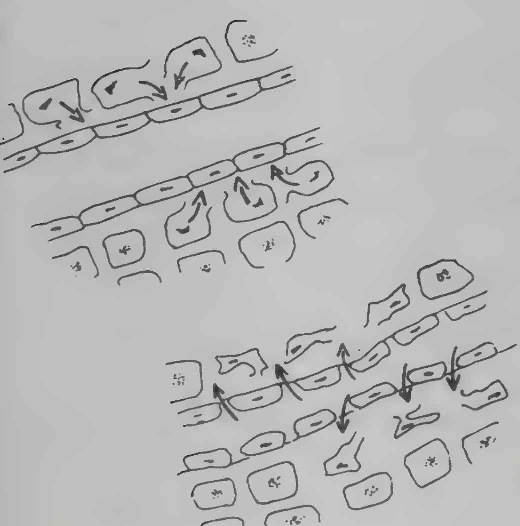
6 Vascular injury causes edema: Capillary vessels are also crushed by the bullet, and they leak fluid into the tissues. Increasing volumes of fluid **between** the cells further obstruct the venous drainage → increasing cellular edema.

7



7 Vascular cell hypoxia causes edema: The capillaries are lined with endothelial cells. Endothelial cells regulate the vascular wall permeability but they need oxygen for their normal function. The artery injury and the increasing local edema deprive them of oxygen; they also become damaged and the capillary wall starts leaking fluid into the tissues → increasing edema.

8



8 Chemically induced edema: From the crushed, hypoxic or dying cell several chemical agents are released into the bloodstream. These agents act like a signal to the endothelial cells to change the capillary wall permeability. White blood cells and immuno-proteins are let through the vascular wall into the injured tissue to prevent infection. But water also leaks through the vascular wall → increasing edema.

The response to tissue necrosis (cell death)

The first response:
Pain → increased local blood flow

From the cells killed by the bullet and those dead from hypoxia, chemical agents are flushed into the bloodstream. Within minutes the limb pain nerve receptors are activated, and signal the brain to activate the sympathetic nervous system. Increased sympathetic activity has these effects:

- The pulse rate increases.
- The blood pressure increases.
- Skin capillaries contract in order to shunt more blood to the muscles and vital organs.
- Muscle capillaries become dilated: The blood supply to the injured limb muscle increases during the first hours after trauma. This increased blood flow to the injured limb is a response to the immediate pain, and has a positive function. For the dead cells of the wound track nothing can be done. But the partially damaged cells at some distance from the wound track profit from the increased oxygen supply. It helps prevent edema, and for a while the pain will diminish.

The second response:
Shunting of the blood volume → reduced local blood flow
The limb is bleeding and reduction of circulating blood volume threatens the nutrition of vital organs (brain, kidney, heart, liver). To preserve the vital organ blood supply, the sympathetic nervous system shunts blood away from the limbs into the central organs. Also in the injured limb is a breakdown of circulation when the central shunting occurs. The result is a dramatic and rapid extension of the necrosis around the wound track.

The third response:
Increasing necrosis → hyperactivation of the sympathetic nervous system

Continuous and strong pain for hours after the injury: Did you miss an injury? Can the circulation be improved? Compartment syndrome on the way?

Increasing and ongoing necrosis causes continuous pain in the hours after the injury. Continous pain causes hyperactivation of the sympathetic nervous system: Further shunting of blood from the muscular tissues into the vital body organs → accelerating local edema and accelerating necrosis.

The fourth response:
Infection starts → increasing local edema
Missile wounds are always dirty, and necrotic tissue is a nice medium for bacteria to grow. Within 8-12 hours after the time of injury bacteria invade the muscle cell. Bacteria release toxins into the tissues and bloodstream. The toxins increase the regional blood flow and also the capillary permeability → increasing local edema → extension of the necrosis around the wound track.

Basic life-saving surgery: p. 130 and 153-161.

Prevent the chain reaction of complications – fight the local edema:

- Support airways and breathing: Oxygenation of the blood is one main base for all life support
- Control bleeding and start aggressive volume therapy inside the battlefield: To re-establish perfusion and prevent hypoperfusion is the other main base of life support
- Immobilize open fractures before evacuation. Do early fasciotomy
- Give effective i.v. analgesia before and during the evacuation, morphine or ketamine to serious cases
- Proper surgical debridement should be done within eight hours after the injury

The body response to injury

The circulatory response

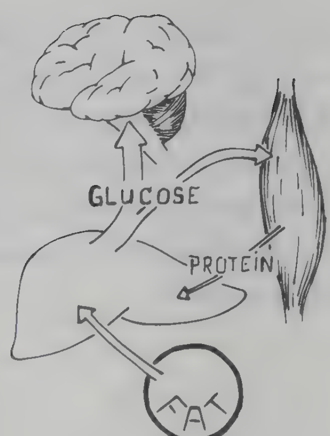
- **Moderate blood loss:** Increased blood pressure, increased pulse rate and shunting of blood from the skin compensate for the blood loss. The skin is pale. There are no signs of circulatory shock.

- **Blood loss less than 20 % (1 liter in adult):** Blood is shunted from muscles and intestines to compensate for the blood loss. The skin is pale, the limbs cool – the first signs of circulatory shock.
- **Blood loss 20-30% (1-1.5 liter):** The shunting of blood cannot compensate for the blood loss. The pulse rate increases but even the increased cardiac output cannot compensate for the blood loss. The blood pressure falls and the central circulation is in danger. This is a state of circulatory shock.
- **Blood loss more than 40% (2 liters):** Despite the shunting of blood to the vital organs and a pulse rate exceeding 120 there is a breakdown of the central circulation. The blood pressure is too low for registration. There is a grave circulatory shock. Vital organs may be permanently damaged if the central cirulation is not re-established immediately.
- **Persistent circulatory shock (more than one hour) → liver hypoxia:** Instead of rinsing the blood of waste products, the liver itself starts to produce waste products. Metabolism of fat and mobilization of glucose from the liver is reduced
  → blood acidosis
  → hypoglycemia
  → reduced protection from infection
- **Persistent circulatory shock (more than one hour) → renal hypoxia:** The active kidney pump becomes damaged → the urine production falls below 20 ml/hr
  → risk of permanent renal failure with general edema, acidosis and uremia

Management of renal failure: p. 591.

- **Persistent circulatory shock → cardiac depression:** Hypoxic tissues release myocardial depressant chemical factors into the bloodstream
  → reduced myocardial function
  → less resistance to circulatory complications
  → myocardial infarction

9

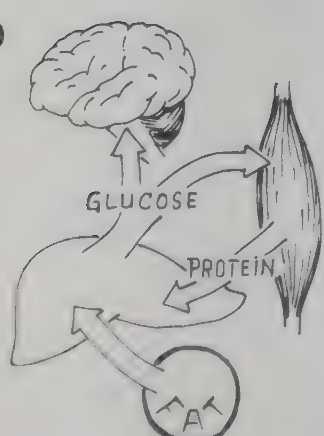


The metabolic response

9 **The immediate response (the first 24 hours after injury)** is caused by the pain signal and chemical agents released from injured tissue:

- Mobilization of glucose from the liver glycogen depot, increased influx of glucose into the cells to meet increased energy demands.
- Mobilization and breakdown of body fat depots, increased influx of free fatty acids and glycerol into the cells to meet increased energy demands.

10



10 **The delayed response (3-2 days after injury)**

- Increased body metabolism.
- Increased metabolism of the injured limb.
- Increased utilization of fat from the nutrition and from body fat depots for production of glucose.
- Breakdown of muscular protein to amino acids, increased influx of amino acids into cells to forward protein resynthesis and tissue regeneration.

Notice: In hunger areas, in fighters exhausted during lengthy fighting, and in patients admitted after long painful evacuation, the glycogen depots in the liver are empty and their blood glucose low. The result is poor metabolic response to injury. They cannot produce the energy (glucose, free fatty acids) needed to

cope with an extensive injury. Without high-energy nutrition from the time of injury their risk of complications is increased compared to that of a well-nourished person. In cases with extensive soft tissue injuries, the amino acid demand for tissue regeneration is enormous. If those cases do not get protein-enriched nutrition, the body "steals" protein from non-injured tissues and utilize it in the injured area, and "self-cannibalism" develops.

For details, see p. 601.

Side effects of pain

The pain at the time of injury is useful. It mobilizes the protective mechanisms of the body. But continuous pain has effects that increase the risk of serious complications:

- **Irregular and superficial respiration**
  → reduced blood oxygen
  → collapse of the lower segments of the lung
  → pneumonia
- **Hyperactivity of the sympathetic nervous system**
  → vomiting, aspiration
  → stomach stress, gastritis and ulcers
- **Mental depression and physical inactivity**
  → venous thrombus formation
  → poor general condition
- **Increased cardiac load**
  → cardiac infarction in the hypovolemic patient

Multi-organ failure (MOF)

Monitoring after surgery: p. 582.

In serious injuries a variety of chemical agents are released into the bloodstream from injured tissues. In some patients these agents start an explosive chain reaction of complications causing failure of more than one vital organ. The details of this reaction are not yet fully understood; management is difficult, and even in specialized trauma centers the mortality rate is high. The best strategy is to prevent these complications arising. The main features of MOF should be known and recognized by the war surgeon.

Table 1
The risk cases to develop MOF

Type of injury	Points
Flail chest, lung contusion	10
Aspiration	10
Intestinal perforation, peritonitis	5
Lasting circulatory shock	5
Brain contusion	5
Femur or pelvic fracture	5
Arm or tibial fracture	3
Other unstable fractures (per fracture)	2
Septicemia	10
Multiple blood transfusions	5

Assess the risk of complications for all major injuries as a part of the clinic triage. Note on the Patient Chart. A patient with sum of 10 risk points or more on this scale carries high risk of MOF. He is a T1 case (p. 125).

Management of respiratory failure: p. 588.

The adult respiratory distress syndrome (ARDS)

One or two days after injury:
- Microemboli in lung capillaries
- Defects in the alveolar membrane
  → moderate lung edema, hypoxemia
  → risk of atelectasis and pneumonia

Four or five days after injury:
- Massive embolism in lung circulation
- Thick alveolar membrane
- Lung edema
  → manifest lung failure, ARDS

Management of coagulation system failure: p. 593.

Coagulation system failure

Days or weeks after injury:
- Multiple microemboli in the vessels throughout the body tissue disseminated intravascular coagulation – DIC
- Consumption of blood platelets
  → total imbalance in the coagulation system
  → tissue hypoxia and organ failure due to artery emboli
  → general tendency for spontaneous bleeding

Management of renal failure: p. 591.

Renal failure

Hours after injury:
- Renal hypoxia due to persistent circulatory shock → decrease in the urine production or anuria

Days or weeks after injury:
- Infarction of the kidneys due to DIC
  → decrease in the urine production or anuria

Liver failure

Hours after injury:
- Liver cell necrosis due to persistent circulatory shock
  → hypoglycemia
  → reduced synthesis of protein
  → mental confusion
  → increased serum bilirubin and clinical jaundice

The liver has high capacity for regeneration when injured. The depression of the liver function after circulatory shock is seldom permanent and will improve spontaneously. The late liver failure may, however, be serious. Days and weeks after injury:
- Progressive liver cell necrosis due to DIC
  → increasing liver failure that may become permanent

Prevent systemic complications by

- Forward and competent basic life support
- Forward emergency surgery and autotransfusion on unstable cases
- Short operation time and central warming on hypothermic cases
- Early high-energy nutrition to extensive injuries and undernourished patients

Points to note – Chapter 5

Assess the vital functions during a two-minute clinical examination

- find out if the airways are free: p. 105. Methods to establish free airways: p. 136
- find out if the respiration is sufficient: p. 136. Methods to support the respiration: p. 140
- find out the degree of circulatory shock, and how much blood is lost: p. 107. Volume therapy to bleeding patients: p. 145
- the vital signs in injured children are different: p. 108 and 262
- the response to injury in old people is different: p. 264
- study the Injury Chart on p. 52, the Patient Chart on p. 53, and the Vital Function Index on p. 700 to assess the vital functions and the local injuries

Study the clinical signs of abdominal injuries to find out

- which cases need exploratory laparotomy: p. 111 and 355
- which cases need emergency laparotomy: p. 155 and 157

Pelvic injuries are often serious due to internal bleeding, intestinal injuries, and urinary tract damage

- know the signs of bleeding inside the pelvic cavity: p. 108 and 113. How to manage pelvic bleeding: p. 468
- know the signs of intestinal damage: p. 110. Diversion enterostomy as an emergency measure: p. 378. Or tie the intestines: p 157
- study injuries to the urethra, and precautions to take when bladder catheter is inserted: p. 434 and 436

Most artery injuries are missed at the time of the first examination

- note the signs that should make you suspect artery injury: p. 114
- when neurological signs develop, it may be too late to repair an artery injury: p. 187
- why early fasciotomy should be done in artery injuries: p. 177
- learn the anatomy of limb nerve trunks; nerve function tests can help you identify vascular injuries: p. 120

Learn to assess a head case during a one-minute examination to find out

- if there is brain damage: p. 115 and 301
- on which side of the brain is the injury: p. 116
- if the brain is dead: p. 116
- know the signs of increasing brain pressure: p. 301
- know the signs of a skull hematoma: p. 299
- study the Head Injury Chart: p. 55, and the Glasgow Coma Scale p. 701

5 The clinical examination

First things first: Assess the vital functions and start basic life support before you examine the regional injuries. The four targets of basic life support are

A – airways
B – breathing
C – circulation
Pain

When his airways are free, his respiration satisfactory, bleeding controlled, and with infusions running and i.v. analgesics given – then examine the regional injuries:
- **Undress the patient!** Wash all blood and dirt with soap and water. Too many injuries are missed because inlet wounds are covered by dirt or clothes or the wound is located in the perineum, the buttocks or in the back.
- **Work systematically!** You spare time making one thorough examination rather than several superficial ones. In this chapter we propose a stepwise routine to follow. You may follow this routine, or make your own. But do not ever leave your routine – a missed penetrating injury may be a catastrophe.
- **More than one injury?** When one injury is identified, always look for the second and the third. In war surgery missed multiple injuries in one patient are the most common diagnostic failure.
- **Exact registration in the Injury Chart there and then!**

Quality control programs – determine the Vital Function Index: p. 700.

The Injury Chart: p. 52.

Assess vital functions – pain and anxiety

Pain causes:
- Rise of PR and BP: It may hide the clinical signs of circulatory shock.
- Respiratory distress: It may mislead you in the assessment of the respiration.
- A tense abdominal wall: It makes abdominal examination difficult.

For casualties in obvious pain and/or anxiety, give analgesia before further examination:
- I.v. morphine 0.1 mg/kg (adults: 5-10 mg), or
- I.v. ketamine 0.5 mg/kg (adults: 25-50 mg)

Assess vital functions – airways and breathing

The specific procedures for management: p. 344.

Drain a penetrating chest wound immediately!

A chest wound bubbling with the respiration in an unstable patient may indicate a valve (tension) pneumothorax (p. 260). There is communication from the airways into the pleural space, but the injured pleura acts like a valve: Air leaks out of the lung by inspiration but cannot leak back. The result is increasing pressure in the pleural space and progressive collapse of the lung. As first aid, enlarge the wound (scissors, two fingers) to let the air pass easily until you can pass a chest tube and close the wound (temporary suture or a tight dressing).

Listen!

Is the respiration wet or bubbling? Clear the mouth and throat with your finger.

1

1 **Wheezing** during inspiration indicates some kind of obstruction (swelling or foreign body) in the upper part of his airways. Indication for endotracheal intubation? Emergency tracheotomy?

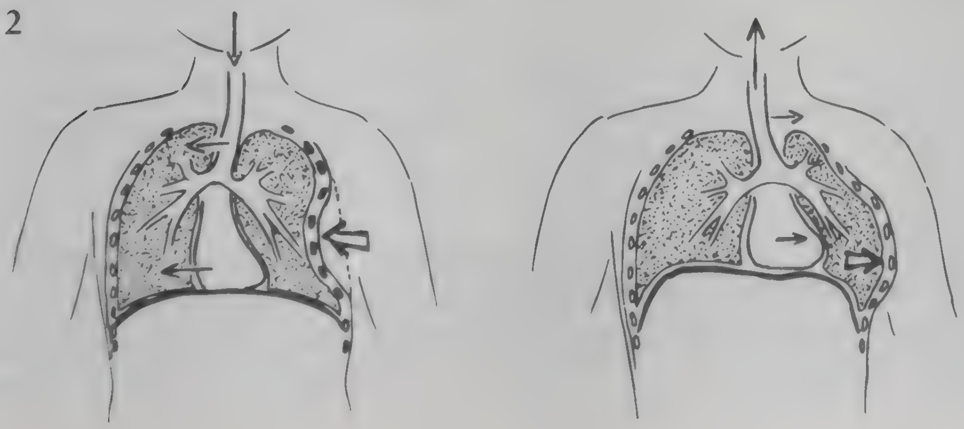
Rapid and shallow (dog-like) respiration indicates chest wall injury. Or abdominal injury. Or the respiration may simply be distressed because of pain and/or fear. Give analgesics, then re-examine.

Look!

Thoracic or diaphragmatic breathing? See p. 630.

Does he **vomit?** Put him in a stable side position to avoid gastric content entering his airways. There may be a combined chest-abdominal injury.
Cyanosis of face, nail beds or palms? If so, he needs urgent respiratory support. In casualties with hemoglobin less than 5 g/100 ml it is not possible to see the cyanosis.
Study the face: In the face of a patient with respiratory problems you can read his anxiety.

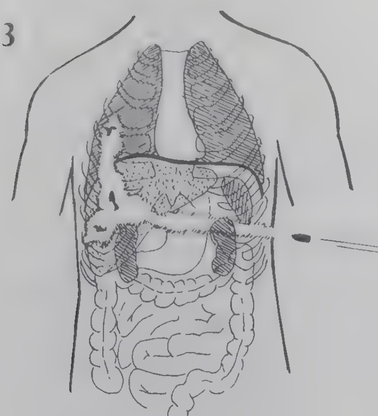
2



2 **Look at the chest movements during respiration:** Paradoxic movement of parts of his chest, indicates "flail chest" due to multiple rib fractures. Retractions in the epigastric area or over the lung tops with the inspiration indicate considerable respiratory distress.

Examine the chest!

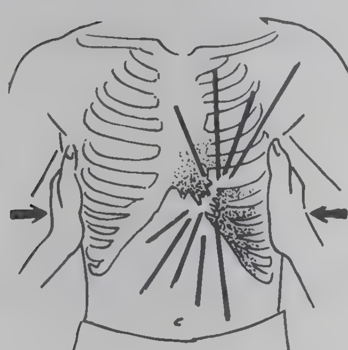
3



3 Do not miss the chest injury: A high-velocity projectile with an abdominal inlet wound may well cause chest injury. **Notice:** The base of the lungs is at level with the upper abdominal organs, and combined thoraco-abdominal injuries are common. Fractures of the distal six ribs may well be associated with abdominal injury. **Notice:** The top of the lung may reach above the clavicular bone.

Palpate the chest wall: A swelling with fine crepitations (like the sound produced by crushing fine paper) under your fingers indicates subcutaneous emphysema. Somewhere there is a tracheal or pleural injury.

4

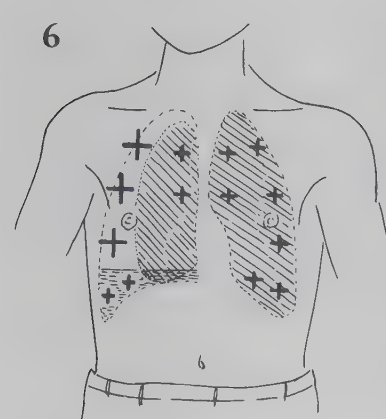


4 Press the chest between your both hands. Indirect pain indicates chest wall fracture.

> ### Pneumo-hemothorax
>
> It is a common and serious wartime injury. Diagnosis should be made at the site of injury based on clinical examination. Management must not be delayed due to lack of X-ray facilities:
> **Pneumothorax:** Air leaks from the lung into the chest cavity, and the lung collapses.
> **Hemothorax:** Bleeding into the chest cavity, the hematoma compresses the lung.
> **Pneumo-hemothorax:** A combination of both conditions, the most common injury.

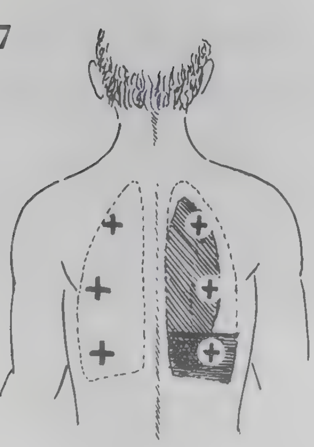
5

6



5, 6 Percussion: Your right 3rd finger is the "drum stick", your 3rd left finger on the chest is the "drum plate". Always compare one side with the other at the same level, and seek any difference between the two sides. Over the uninjured part of the lung the drum sound is resonant (plus). Over the hemothorax the drum sound is dull (small plus). Over the pneumothorax the drum sound is hyper-resonant, that is a drum sound of greater volume than normal (big plus).

7



7 Auscultation: Again compare the sounds of both lungs at equal levels. Over the uninjured parts you can hear the normal respiration sounds (big plus). Over the pneumothorax and over the hemothorax the sounds are weak or absent (small plus).

Dull drum sound and weak stethoscopic lung sounds:
Hemothorax → insert chest tube!

Hyper-resonant drum sound and weak stethoscopic lung sounds:
Pneumothorax → insert chest tube!

Hyper-resonant drum sound at top level, dull drum sound at the lung base and weak stethoscopic lung sounds:
Combined hemo-pneumothorax → insert chest tube!

Problem: You are in doubt if there is hemothorax or not. Eg. he has slightly dull drum sound and slightly weak lung sound due to a lung contusion with some blood in the lung tissue. He may well have such an injury without pneumo- or hemothorax. Or he may have a blast wave injury of one or both lungs (p. 82). Or he may have a small hemothorax. Or there is too much noise around for you to assess his lung sounds. If you are in the least doubt, insert a chest tube!

Problem: There are no signs of airway/chest injury, but still his respiration is distressed. Either he has brain/spinal cord injury that affects his respiration. Or he needs more analgesics or tranquilizers. Or this is a blast wave lung injury.

Assess vital functions – circulation

Assess the circulatory state

Pain may mislead you; it makes the skin cold and clammy. Warm skin is definitely a good sign.

- Finger-toe-test: The skin on both hands and both feet is cool and pale.
- "The white fingerprint test": Press your finger firmly on his sternum, remove it and study the time for capillary circulation to "fill" the white fingerprint: Normally it takes 3-5 seconds; if the peripheral circulation is reduced, refilling is slower.
- In children: The nose tip is cold.
- Blood pressure and pulse rate are normal.

This is first degree of circulatory shock. Less than 20% of the blood volume is lost (less than 1 liter in an adult).

Brain or cervical spine injury: BP and PR may not respond as normal. Assessment of the circulation must be based on
- skin color and temperature
- identification of the bleeding source
- a rough estimate of blood volume lost.

- The skin blood circulation is reduced.
- The pulse rate rises towards 120.
- If bleeding continues, the blood pressure will start falling.

This is a state of circulatory shock. More than 20% of the blood volume is lost (more than 1 liter in an adult). If he bleeds still more, the central organs are in danger.

- Skin blood circulation is reduced.
- The pulse rate is high.

• The systolic blood pressure is below 80-100 mm.
This is a state of grave circulatory shock. More than 40% of the blood volume is lost (more than 2 liters in an adult). Central organs are in danger.

• Circulatory shock.
• Bladder catheter: The urine production is less than 0.5 ml/kg body weight/hour (adult: 25-50 ml/hour).
He has been in grave circulatory shock for one hour or more. There is a hypoxic injury of the kidneys. There is immediate risk of cardiac failure and brain damage.

Management of circulatory shock: p. 143.

An example: One patient had an extensive burn five hours before admission. The infusions during the evacuation have been insufficient. At admission his skin is cold and pale, PR 120, systolic blood pressure 80 mm. He delivers 75 ml urine by the bladder catheter: 75 ml urine during five hours is a mean of 15 ml/hour. Immediate aggressive volume therapy is needed.

Children are different!
• BP is not a good indicator of shock. Children may gradually lose blood, their skin is cool and clammy, their PR increased. But the BP may stay normal – until it suddenly drops towards zero. Then volume therapy may be ineffective and the shock irreversible. Also youngsters may react the same way.
• The parameters in children are different. An infant has a normal PR 140. See table on p. 261.

Identify the bleeding source – assess the blood volume lost

Blood loss in limb injury

The identification of external bleeding is simple. Do not overestimate the external blood loss: 100 ml blood makes an impressive staining (30-40 cm wide) on the cloth. The diagnosis of internal limb bleeding is often missed:
• Undress the patient completely
• Check pelvis and all limbs for fractures
• Check the major limb compartments for swelling
• Check all limbs for vascular injury

Table 1
Estimated blood loss (in ml) in limb injuries

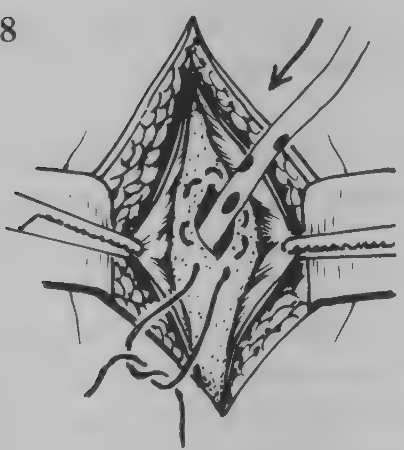
Site of injury	Closed fracture	Compound fracture	Compartment syndrome
Arm	500	1000	1000
Forearm	250	500	200-500
Thigh	1000	1000-2000	1000-2000
Lower leg	500	1000	1000
Pelvis	more than 1000	more than 2000	

Blood loss in chest injury
Chest tube insertion is diagnostic. Use tube suction and assess the volume drained. Less than 200 ml in a hemothorax may not be drained by the chest tube, and not seen on a standard chest X-ray. Continuous rapid draining of 1500 ml blood by the first chest tube → urgent thoracotomy.

Blood loss in abdominal injury
- Abdominal wall and retroperitoneal injury: Major hematomas may collect in the spaces between the muscles of the abdominal wall and behind the peritoneum. Examine the flanks and groin if there is local swelling and tenderness.
- Penetrating injury: Minor high-velocity fragments (less than 5 mm) may cause serious abdominal bleeding. The inlet wound may be tiny: Undress completely, wash blood and dirt, examine closely. Also the backside!
- Possibly penetrating injury: Consider peritoneal lavage.
- Blunt injuries, entrapment cases, blast wave cases: Blood loss into the retroperitoneal spaces, rupture of liver and spleen. Consider peritoneal lavage.

easons to do emergency
parotomy: p. 156.

8



8 **Diagnostic peritoneal lavage** can be done under local infiltration or low-dose ketamine anesthesia through a small midline incision under the umbilicus. Enter through the rectus sheath exactly in the midline. Insert a soft catheter (the infusion set tube with side holes). Tie a purse-string suture around the tube and close the incision tightly. Flush 1 liter of saline from the infusion bag. Let the fluid out again immediately by putting the infusion bag on the floor. If you can read a newspaper through the bag of pink water emerging, there is no major bleeding in the abdominal cavity. There may be a retroperitoneal hematoma, but in that case the patient should not be operated on.

Mass casualties: Do not waste time on BP measurements; cool limbs and high PR indicate blood loss and volume therapy.

Examine the regional injuries

Take an exact history of the weapon that caused the injury:
- Low-velocity penetrating injury: Most likely the internal damage is moderate. The risk of multi-organ injury is small. You may save extensive examinations and exploratory surgery.
- High-velocity penetrating injury: Most likely the internal damage is extensive. Failing to note associated injuries is a common mistake. Examinations should be comprehensive and exploratory surgery aggressive.
- Blast wave injury: The clinical signs of chest and abdominal organ injury develop slowly. Re-examine every 6 hours until 48 hours after the injury.
- Mine injury: Was this a fragmentation mine? If so, do not miss a penetrating pelvic or abdominal injury. Traumatic thigh amputation? If so, there is also risk of blast wave pelvic and abdominal injury.

Rifle bullet injury: What kind of ammunition was used? See p. 517.

Abdominal and pelvic injury

Your examination should answer three main questions:

- **Question one:** Has the missile entered the abdominal cavity (penetrating injury) – or not?
- **Question two:** Is he bleeding inside the abdomen? Is the bleeding increasing, receding or has it stopped? Bleeding penetrating injuries have first priority for surgery. Emergency laparotomy may be indicated.
- **Question three:** Are there associated injuries – or not? The same missile may cause damage to the chest, the cord and spinal nerves, pelvic bones and lower limb arteries.

Regarding question one

First – look: Does the abdominal wall move freely with the respiration? If not the reason may be abdominal wall injury, intra-abdominal injury, peritonitis or spinal injury.
Then – listen with the stethoscope: Poor or no bowel sounds indicate abdominal injury. **Note:** You should listen continuously for one minute at least.

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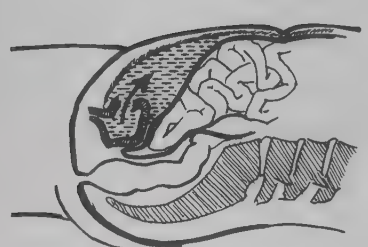

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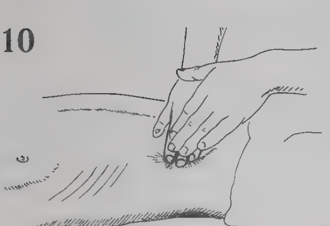

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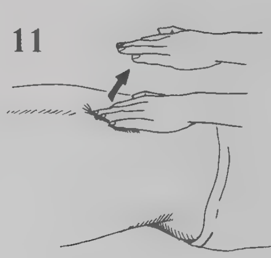

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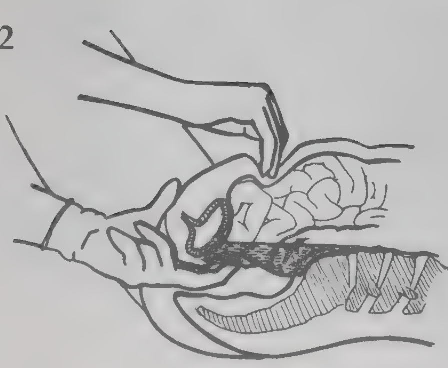


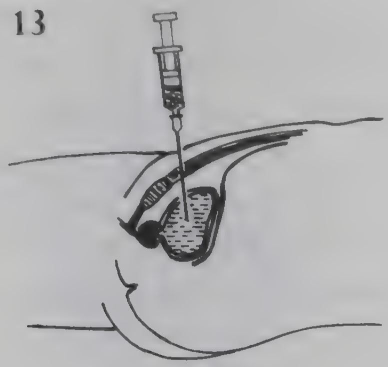
9 **Then – percussion:** Examine all sections of the abdomen. The normal drum sound should be heard over the anterior abdominal wall. Dull percussion sound in one flank indicates a collection of fluid (pus, blood or urine). Dull percussion sound above the pubic bone indicates an enlarged bladder, or leaking of free urine from a bladder tear. Inside the pelvic cavity large amounts of fluid may collect before the percussion sound turns dull; rectal examination is diagnostic.

10 **Then – palpation:** Tell the patient to relax and breathe deeply. Perform superficial palpation of every part of the abdomen. Gently press the abdominal wall with one hand. **Deep palpation:** Use both hands, one superimposed on the other. Palpate every abdominal organ, including the deep structures.
In children: The child will relax when you use the child's hand for your palpation.

11 **Withdrawal pain:** During the palpation, press the abdominal wall slowly – then suddenly remove your hand. The withdrawal pain is a main indication of peritonitis, or peritoneal irritation due to bleeding.

12 **Then – exploration of the rectum:** This is the only route to the deep pelvic structure. It is mandatory in all cases with abdominal or pelvic injury. Collections of fluid in the pouch between rectum and the bladder or uterus may be felt. Also search for retroperitoneal hematomas inside the pelvic walls. When finished: Is there blood on the glove? Diagnostic aspiration from the Douglas' pouch: p. 447.

13



13 Diagnostic bladder puncture or suprapubic bladder catheter should be a routine procedure. If there is hematuria, collect urine in glasses at regular intervals to see if the bleeding is increasing or receding. Never force the bladder catheter: Resistance in urethra may indicate an urethral tear and the catheter may tear it more. In that case, perform a diagnostic bladder puncture (infiltration anesthesia) with (spinal) needle in the midline just above the pelvic bone.

- **Use of naso-gastric tube** should be a routine procedure in all abdominal cases. It is diagnostic – blood in the stomach? And routine respiratory support, it relieves the pressure from a stomach filled with fluid and gas (gastric decompression).
- **Check the femoral artery pulse volume:** Reduced pulse volume on one side may indicate iliac artery injury. That indicates risk of injury to neighboring structures: ureter, colon and rectum.
- **Referred pain:** Hematomas under the diaphragm may cause pain at the shoulder girdle on either side. Hematomas from a liver injury may cause referred pain to the right shoulder, hematomas from a splenic injury to the left shoulder.

Draw your conclusions

The abdominal respiratory movements are superficial, or there is only thoracic respiration. There are poor or no bowel sounds. There is withdrawal pain:
→ There is an abdominal injury. If there are no inlet wounds, examine the history carefully as this might be a blast wave case.

There is local abdominal wall tenderness with superficial palpation. There is local swelling:
→ There is an abdominal wall injury. There may be a retroperitoneal hematoma. Consider peritoneal lavage.

Abdominal distention soon after the injury indicates severe abdominal bleeding; do emergency laparotomy.

There is general abdominal wall tenderness with superficial palpation:
→ There may be a peritonitis. In a penetrating injury this is indication for laparotomy.

The abdominal wall is stiff; you cannot make deep palpation:
→ There is a peritonitis. There is indication for urgent laparotomy.

There is localized deep pain with deep palpation:
→ There is an abdominal organ injury. Identify the possible bleeding source and the actual organs injured by rectal exploration, bladder catheter, naso-gastric tube, pulse examination and the pattern of pain.

Regarding question two

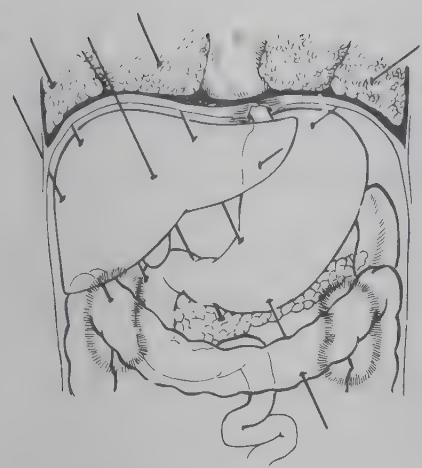
Consider peritoneal lavage

The procedure is recommended to decide whether to do exploratory laparotomy or not in blunt injuries. It may also be useful in penetrating abdominal injuries if assessment is difficult due to other associated major injuries. Or you can do a diagnostic lavage while the BLS team do the resuscitation. Diagnostic lavage is a sensitive examination for bleeding into the abdominal cavity. It is not

Regarding question three

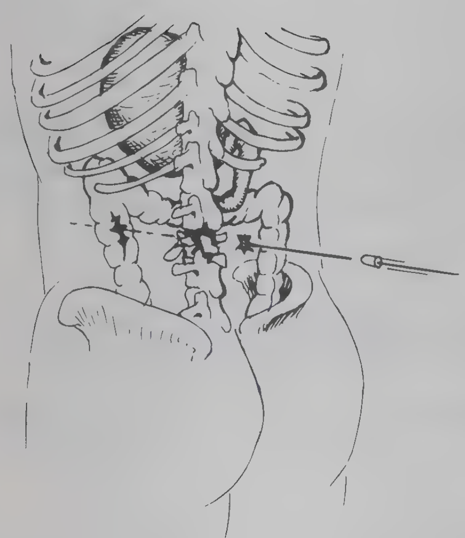
time consuming in the experienced surgeon's hands. You may also use lavage to monitor an intra-abdominal bleeding: If the catheter is left in place for 24 hours, the lavage may be repeated in order to monitor bleeding. The problem is often to decide whether a bleeding is retroperitoneal or intraperitoneal: No external bleeding, persistent circulatory shock regardless of aggressive volume therapy, combined with a slightly pink lavage fluid, indicate retroperitoneal bleeding. If you are unfamiliar with peritoneal lavage: One and the same doctor should perform repeated abdominal examinations at hourly intervals. Monitor the fluid intake/output-balance and his circulation hourly.

14



14 Combined injuries are common: Observe the close relation to the lungs and heart. In the anterior and posterior sections the lungs extend even more distally than illustrated here; they cover the upper abdominal organs as a cap. Observe the proximal position of the kidneys (shaded); the kidneys belong to the upper abdominal organs. **Pelvic injury:** The loops of the small gut are located deep in the pelvic cavity. The bone of the pelvic wings is easily penetrated by missiles, and injury to internal organs must be excluded in all missile pelvic fractures.

15



15 The posterior abdominal wall: Whether the high-velocity bullet hits the spine or not, there will be a large cavitation effect inside the posterior abdominal wall. The organs on the posterior wall may be damaged. Often the bleeding or perforation is outside the peritoneum, and the early clinical signs of abdominal organ injury may be few.

Do not probe a wound in the anterior abdominal wall. The wall consists of several structures that move independently. You cannot decide by probing whether the wound track is superficial or not.

Associated injuries

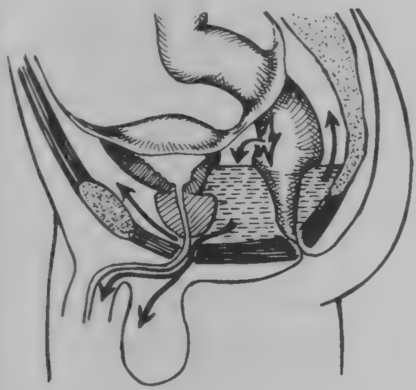
- Penetrating chest **and** abdominal injury: The chest injury has priority. Insert a diagnostic chest tube and consider the indication for thoracotomy. When the chest injury is stable or managed, the abdominal injury is explored through a separate midline incision. There is no need for peritoneal lavage.
- Penetrating pelvic injury: The abdominal organ injury has priority. In high-velocity injuries consider laparotomy. In low-velocity injuries consider peritoneal lavage.
- Penetrating posterior abdominal wall injury: Consider lavage. Examine the abdomen closely regarding perforations of the intestine. Even if the lavage is negative, deep abdominal tenderness indicates laparotomy with exploration of the retroperitoneal parts of duodenum and colon.
- Penetrating spinal **and** abdominal injury: The abdominal injury has priority. Perforations of the intestine should be closed before the spinal injury is explored. There are strong indications for laparotomy even if the lavage is negative.
- Head **and** abdominal injury: If the patient is in coma, the abdominal wall will not be tense – even if there are abdominal bleeding and peritonitis.

The general rule in war surgery
All penetrating and "possibly penetrating" abdominal injuries should be explored surgically within eight hours after the time of injury.

Examination of pelvic injury

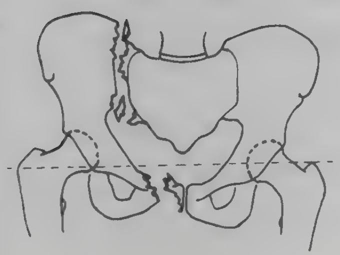
16 The pelvic venous network is rich and lies close to the pelvic bone ring. Even minor fractures may cause considerable venous bleeding. Also the pelvic organs are well vascularized. Thus as pelvic missile injuries bleed much, large hematomas may collect in the loose connective tissues of the pelvic cavity. Penetrating injuries often involve the large colon and rectum. **Notice:** The loops of the small gut are not illustrated here. In penetrating missile pelvic injuries, the small gut is the organ most often hit. There is thus high risk of abscess formation in hematomas not drained. **Notice:** Manipulation of pelvic wound tracks may cause profuse bleeding: Have a gauze band ready at hand for tamponage (p. 366).

7



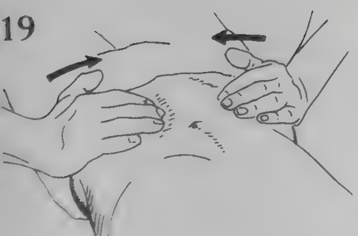
17 Intra- or extraperitoneal injury? Note the two main compartments of the pelvic cavity – inside the peritoneum and outside the peritoneum. Intraperitoneal pelvic injury: The early clinical signs may be poor and the diagnosis easy to miss. Extraperitoneal pelvic injury: Blood, urine, feces or pus collect along the pelvic floor and may be identified by
- Rectal exploration
- Exploration through the inlet wound with a glove finger
- Fecal smell from the wound track
- Swelling and bruising above the pubic bone, in the scrotum or perineum
- "Abscess fever" (p. 459) 3-5 days after the injury

8



18 Pelvic fractures: Suspect pelvic fractures after crush injuries, heavy blast wave injuries and in trapped patients. The typical case is one with pelvic pain and circulatory shock (the fracture hematoma may contain 2 liters or more). Bone fragments may tear the bladder, urethra, rectum or major vessels. The examination:
- Bladder catheter or suprapubic puncture
- Rectal examination
- Femoral pulse examination
- Unequal length of the lower limbs?
- Stability of the pelvic bone ring

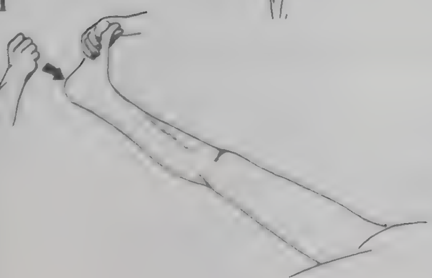
19



20

19, 20 Test for stability of the pelvic ring: Is there indirect pain?

21



21 Hip joint fractures: Indirect pain in the hip joint area indicates fracture close to the hip joint. Unequal leg length? Fragments of the pubic bone with acetabulum may be displaced into the pelvic cavity.

Buttock missile injuries – risk of gas gangrene

Inside the large buttock muscles you often find wound tracks more than 10 cm long. That implies extensive deep necrosis after most types of high-velocity projectile hits, in particular when there is also a compound fracture. A small inlet wound makes favorable conditions for gas gangrene. Explore buttock wound tracks with your finger to roughly estimate the extent of tissue damage.

Vascular injury

The clinical diagnosis of vascular injury is difficult, and diagnosis is often missed at the first clinical examination. Delayed diagnosis makes surgery difficult and complications common. Note:

- **Most vascular injuries do not have external bleeding:** Most total ruptures of major limb arteries are silent with slowly increasing hematomas under the muscle fascia. Even more silent are the partial vascular tears.
- **In circulatory shock the bleeding stops:** Bleeding may start again during the evacuation when volume therapy becomes effective.
- **The signs of distal ischemia develop slowly:** For some hours a certain blood supply is maintained by minor collateral vessels. Or there is an intimal injury that gradually becomes obstructed by thrombosis.
- **The signs of circulatory shock may mislead you:** The local signs of vascular injury are a pale and cool skin. But so also are the limbs in circulatory shock.
- **The direct bullet hit on a major artery is uncommon:** Most vascular injuries are caused by fracture fragments tearing the artery, by shock wave intimal injuries and by blunt crush injuries.

If you are in doubt regarding the diagnosis: Re-examine every hour for four hours. If you are still in doubt: Do surgical exploration.

Look – and compare both limbs

- The skin is more pale distal to the wound track than proximal (an early sign).
- There is swelling around the wound track (an early or late sign).
- There is edema distal to the wound track (a late sign).

22

Palpation – compare both limbs

- The skin is cool distal to the wound track (an early sign).
- The muscle compartments around the wound track are hard and may be painful (an early or late sign).
- The distal pulse volume is less compared to the opposite limb (early sign).

22 **The sites for pulse volume testing:** These are also the pressure points where you control distal bleeding.

- The carotid artery
- The brachial artery
- The radial artery
- The iliac artery
- The femoral artery
- The popliteal artery
- The posterior tibial artery
- The dorsal foot artery

Test – and compare both limbs

- The capillary circulation is slow – fingerprint test: Press your finger against his skin for some seconds, then let go. Study the time for blood to refill the "white" fingerprint (an early sign).
- Test the function of the fellow nerve (p. 120): On most levels, the main arteries are accompanied by one main vein and one main nerve. Damage to the nerve indicates risk of artery injury (an early sign).
- Test the nerve function of the injured limb: Gradually reduced blood circulation will cause ischemic damage of all limb nerves. The clinical sign is patchy and increasing paralysis and loss of sensation (a late sign indicating urgent surgery).

Venous injury

This injury of the limbs is of less interest. Exceptions are the common femoral vein and the popliteal vein. These should be reconstructed due to poor collateral venous network. There are few early clinical signs of venous injury. Pose a "may be" diagnosis if the wound track direction is towards the two veins, and there is a high-energy injury.

Head and neck injury

> **Warnings**
>
> Any head injury also has a neck injury until your examination proves otherwise.
>
> Manipulation of a spinal injury may be dangerous and even fatal. Any patient who presents a head injury, neck pain or back pain:
> - Ask if he has full sensation in arms and legs.
> - Ask if he felt or feels radiating sensations in his arms or legs.
> - Test that he has full motor and sensory function in arms and legs.
>
> Then you may proceed with your examination.

Check the level of consciousness

Fill in the Injury Chart: p. 52.

Also see the Glasgow Coma Scale: p. 701.

- No confusion
- Confused
- Responds to sound
- Responds to pain
- No response to pain. Pain test in a patient in coma: Press the orbital rim or pull the hair in front of the ear.

Test the pupil reaction

- Study the pupils carefully: Are they of equal size?

- With torch: Cover one eye and see how the pupil reacts to light. Compare both eyes: Do the pupils contract equally rapidly? Do they contract as much on both sides?

How to read the pupil's reaction:
One patient has an open fracture in the left temporal region from a small high-velocity shrapnel four hours before admission. He is confused. His **left** pupil is bigger than the right one. His **left** pupil contracts more slowly to light stimulus. Conclusion: He has a brain injury in the **left** part of the brain.

Another example: One patient is found trapped inside a house four hours after an air attack. There are contusions on his head but no signs of fracture. Both eye pupils are widely dilated and do not react to light stimulus. Conclusion: His brain is dying or dead.

Test the nerve function in arms and legs

"Lift your leg – and the other! Press my hand – and the other!" Test roughly the skin sensation of all limbs (needle pin). In comatose patients: Pinch the skin and study the muscle reaction to pain.

Register exact clinical signs and the exact time

Even a minor skull injury may cause serious brain complications. There is no "minor head injury" until the case is repeatedly examined.

The change of condition is the most important sign in diagnosis of brain injuries: Does he slowly become more confused (an expanding hematoma inside the skull)? Does a poor pupil reaction improve during some hours (decreasing brain edema)? For a skull case under evacuation from the front line, there is only one way of continuous registration: Order repeated examinations at fixed intervals; each medical officer notes in the Injury Chart the exact time and results. The level of consciousness, pupil size and reaction, limb nerve function should all be monitored.

Examine the skull injury

Wash all scalp wounds, cut the hair and retract the wound edges for inspection: Can you see a fracture? Explore the skull gently with your finger or forceps: Can you feel a fracture line? Note that the skull bone consists of an outer and an inner table. Even if the outer table of a skull fracture fragment is not depressed, the inner table may penetrate the dura and damage the brain (p. 297). Do not manipulate the fragments of a skull fracture or remove any penetrating foreign body during the examination; that is a case for surgery.

Signs of extensive brain injury
- Dilated pupil/pupils with slow reaction to light
- Irregular respiration
- General convulsions
- Also the pulse rate and body temperature may be affected, varying from case to case

Look for neck fracture or dislocation

- Press each cervical vertebra, first gently, then forcefully with your finger. Ask about local pain or sensations into his arms at each vertebra examined.
- Ask him to rotate his head and flex his neck carefully: Ask about neck pain. Look for restricted movements in any direction.

> If you are in doubt, manage the case as a spinal injury until X-ray examination is done: Continuous manual traction until skull traction or a transport neck cast is arranged. Traction weight 5 kg (adult).

Spinal injury

Are there associated injuries? The spine constitutes the posterior wall of the thoracic, abdominal and pelvic cavity. In missile injuries of the spine always examine chest and abdomen and insert bladder catheter before you turn the patient into prone position.

Exclude spinal cord damage before you manipulate the patient

- Test the limb nerve function roughly.

23

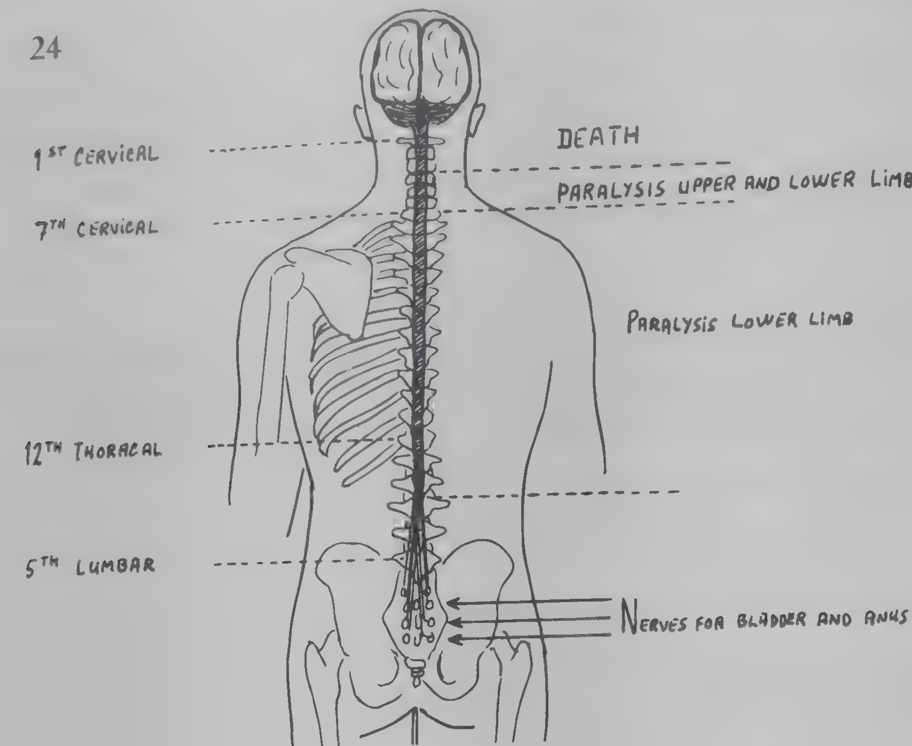
23 • **Test the plantar reflex:** Draw some pointed object or your nail along the sole of his foot. The normal reflex: He flexes the 1st toe. Sign of spinal cord injury: He lifts the 1st toe.

Test for spinal fracture

If there are no signs of spinal cord injury you may carefully put the patient into prone position. Signs of cord injury: Four persons should assist in turning the patient. Maintain continuous manual traction in his feet and head/shoulders until the examination concludes whether there is a spinal fracture.

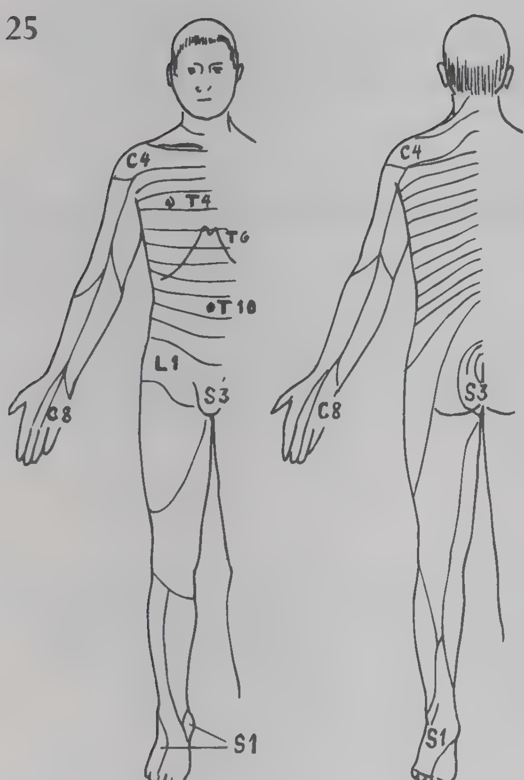
- **Before washing:** Does the spinal wound smell from fecal pus?
- **Test for fracture:** Knock lightly with your fist the spinous process of each vertebra. Pain response is a sign of fracture of that vertebra.
- **Test for fracture:** Wash well. Decide the direction of the wound track by gentle probing with a glove finger or the tip of a soft bladder catheter. A track towards the spine? Is the bone hit? If the exploration of the wound channel leads you deep towards the spinal cord, the diagnosis is "probable spinal cord injury" – even if there are no neurological signs. Leave the final exploration for the surgeon. Note: Any projectile or foreign body located deep inside a spinal wound should be left for surgical removal.
- **Fracture stability:** Without X-ray you cannot assess the stability of a spinal fracture. Any spinal fracture with signs of cord damage, and all missile spinal fractures – neurological signs or not: Handle the case as if the fracture was unstable. Early surgical exploration is necessary.

24



24 Determine the level of spinal cord injury – the motor function: From each vertebral level one set of spinal nerves (left and right) controls sensor and motor function. Test flexion and extension of the shoulder, elbow, hip and knee joints of both limbs. Test the function of the anal sphincter muscle and ask if the bladder control is normal. Eg. paralysis of both upper and lower limbs implies an injury above the 7th cervical vertebra. Paralysis of lower limbs only implies a spinal injury below the 12th thoracic. Normal limb function but paralysis of bladder and/or anus implies injury of the pelvic (sacral) nerve roots, either at the lumbar or sacral level. A major spinal injury above level C3 is fatal in most cases.

25

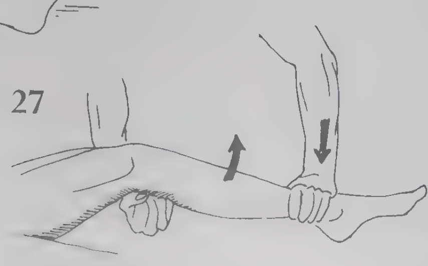


25 Level diagnosis – the sensory function: Each set of spinal nerves control the sensation of a certain skin area – a dermatome. By exact needle-pin testing of the dermatomes you may identify exactly the level of spinal injury. Eg. poor skin sensation of the upper limb and the shoulder implies a high cervical spinal injury. Poor skin sensation below umbilicus implies spinal injury at level T10. Remember the landmarks:

- C4 – the shoulder girdle
- T4 – the nipples
- T6 – the lower end of sternum,
- T10 – the umbilicus
- L1 – the groin/pubic bone
- S1 – the lateral toes

26

27



Fracture and joint injury

Fracture or not?

- Look for angulation and abnormal lie of the limb.
- Look for shortening compared to the opposite limb.

26, 27 Test for indirect pain: Any contusion is painful, fracture or not, when you press directly upon it – direct pain. But only a fracture will cause indirect pain.

More important than the fracture is the extent of soft tissue injury

- High- or low-energy injury? The extent of soft tissue necrosis and the risk of associated vascular injury increase with increasing energy. Projectile fracture: Take an exact history regarding the weapon and ammunition used. Blunt injury: Assess the damaging force.
- Explore the wound track with your gloved finger: How extensive is the soft tissue damage around the fracture? How extensive is the bone fragmentation? Are there free bone fragments without soft tissue attachment?

r documentation in the Injury
art: Classify the fracture (p. 198).
r make a simple drawing of the
acture fragments.

Reduce the fracture roughly by manual traction: The soft tissue necrosis increases during evacuation of displaced fractures. And bone fragments may cause or worsen a vascular injury. Also the reduction lessens fracture bleeding. Field reduction is the conclusion of the primary examination.

Joint injury

The main question is: Open joint injury or not?
Even tiny perforations of the joint capsule will cause arthritis and risk the joint function.

- Look for swelling of the joint (blood or pus).
- Test the passive joint movement and compare to the opposite limb. Joint pain, restricted movement and crepitation indicate joint injury.
- Is the wound track close to a joint? Probe the track direction with a glove finger.
- Open fracture close to a joint: One fracture line may enter the joint creating an inlet for bacteria. Do not trust a negative X-ray in high-energy missile fractures close to a joint: Perform joint aspiration. (Work sterile!) Aspiration of blood from the joint confirms the open joint injury.

The procedure for aspiration of joints: p. 223.

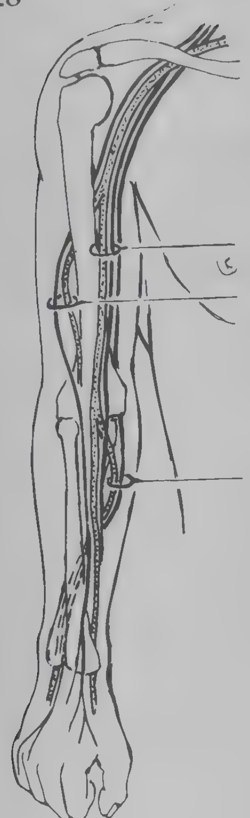
Nerve injury

Do not expect to find total loss of all motor and sensor function of a main nerve after projectile injury. Partial loss of function is common. Either the projectile tore only some nerve fibers or there is edema inside the nerve bundle. Or there is a lack of blood supply to the nerve (compartment syndrome, artery injury). Loss of nerve function is an important diagnostic key: Examine carefully. Always compare to the opposite healthy limb.

Read the internal damage by nerve function tests
Study the exact anatomy of the main nerves of the limbs. A rough nerve function test should be done on all main nerves in a limb case

- in order to diagnose injury to the nerve itself
- and more important, to identify the direction of the wound track, the extent of cavitation, the displacement of fracture fragments, and the risk of associated damage to vessels close to the nerve.

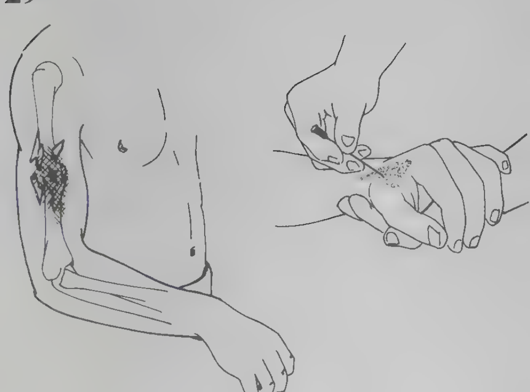
28



28 "Pairs" of nerves and arteries: On most limb levels a main nerve is close to the main vessels. Know by heart the landmarks of nerve anatomy to make use of this diagnostic method. **The upper limb:** The main landmarks are the median nerve with the brachial artery (top); the radial nerve and deep brachial artery; the ulnar nerve and artery (bottom). Eg. in a penetrating missile arm injury there is hardly a loss of radial nerve function without also damage of the deep brachial artery. Eg. a bullet inlet wound on the upper chest: With loss of hand nerve function you can conclude that the wound track is deep and close to the axillary structures. Eg. a compound fracture of the elbow with partial loss of median nerve function: Probably the nerve is compressed by a bone fragment. If there are no clear signs of artery injury, you should still suspect intimal damage of the brachial artery. **The landmarks of the lower limb are:**

- The femoral nerve and femoral artery: p. 678
- The sciatic nerve and femur fractures: p. 121
- The posterior tibial nerve and popliteal artery: p. 531
- The peroneal nerve and the lateral lower leg compartment (the anterior tibial artery): p. 520 and 539.

29



29 The radial nerve: The nerve is at risk in missile arm injuries. It runs close to the bone and is a diagnostic key in arm fractures. Loss of motor function: "Wrist drop", where he cannot extend wrist and fingers. The sensory function: Test this triangle of the first dorsal web space; it is alway innervated by the radial nerve.

30

30 The ulnar nerve: From below the elbow the nerve runs together with the ulnar artery. The nerve is particularly at risk close to the elbow and distally in the forearm where the soft tissue protection is poor. Loss of motor function: He cannot spread his fingers. The sensory function: Both the dorsal and volar skin of the 5th and the ulnar part of the 4th finger are always innervated by the ulnar nerve.

31

31 The median nerve: From the axilla to below the elbow, the median nerve runs close to the brachial artery. Loss of motor function: Loss of finger flexion force (2nd and 3rd fingers). The opponens function of the thumb is always controlled by the median nerve. Tell him to press his thumb against the tip of the 5th finger, and check the force.

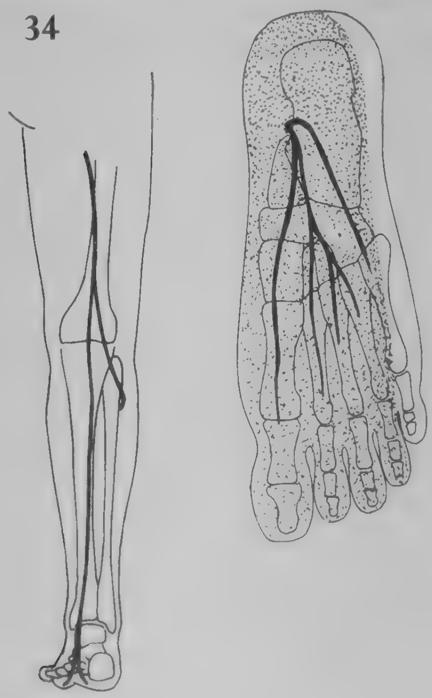
32

32 The femoral nerve: At groin level the nerve runs close to the common femoral artery, and loss of nerve function indicates vascular injury. The nerve spreads out like a horse tail in the anteromedial parts of the upper leg. It is located subcutaneously and is not affected by compartment injuries. Loss of motor function: He cannot extend his knee or contract the quadriceps muscle. The sensory function: The nerve innervates the anterior and medial parts of the thigh.

3

33 The sciatic and peroneal nerves: The sciatic nerve runs close to the femur. It may be damaged by fracture fragments and compartment syndrome of the posterior thigh compartment (p. 518). The peroneal nerve is at risk in lateral injuries at knee joint level. It runs down the lateral leg compartment together with the anterior tibial artery, and is an important indicator of lateral compartment problems. Loss of motor function: Dorsal flexion of the foot and 1st toe is weak or lost. The sensory function: The shaded area is alway innervated by the peroneal branch of the sciatic nerve.

34



34 The posterior tibial nerve: The nerve, which runs together with the popliteal artery, is an indicator of artery injury at knee joint level. Most injuries of the popliteal artery injury are partial with slowly increasing artery obstruction. Increasing loss of tibial nerve function (ischemic) is indicative. Further down the nerve runs with the posterior tibial artery. They are at risk in all deep injuries to the lower leg. Gradual loss of nerve function may indicate posterior compartment syndrome. Loss of motor function: He cannot flex his toes. The sensory function: The nerve always innervates the medial volar part of the foot.

Points to note – Chapter 6

Everybody should know the four triage groups

- study p. 124
- know how to do clinical examination, triage, and to give basic life support to mass casualties: p. 127
- train in routine clinical examination of injured: p. 103
- identify the patients who need immediate life-saving surgery: p. 132

As the condition of patients changes, the triage must be done several times

- how to organize triage and basic life support: see Table 3 on p. 51
- triage and basic life support in the field: p. 36
- triage and basic life support in the clinic: p. 39

The results of the triage must be written, the charts should follow the patient

- for field use, copy the Injury Chart: p. 52
- for clinic use, copy the Patient Chart: p. 53

Notice: In mass casualties, triage is conducted continuously while the basic life support is done

6 Triage – sorting casualties

The principles of triage

> **This is triage:**
> Examining and giving priority to each patient depending on his need for medical support.

Based on experiences since the Vietnam war, we can list the approximate distribution of types of injuries of admitted cases in a war fought with non-nuclear and non-chemical weapons:

Table 1

Type of injury	% of total
Head and neck	15
Chest	10
Abdomen and pelvis	10
Upper limb	25
Lower limb	40

The table gives no information on the degree of injury, and on how serious it is; for the surgeon in the midst of a mass casualty these figures are of no value. They cannot help you to plan a forward clinic, select its staff or estimate its requirement of drugs and equipment. Unlike what is listed in Table 1, triage is sorting injuries on a **quality** base. Thus triage is an important tool in the day-to-day medical management of casualties. Also triage statistics form the basis from which you can plan the requirements of your clinic.

Everybody, military and medical staff, should know the four triage groups!

> **The four triage groups**
> - **Type 1 – T1: Urgent!**
>   This patient needs life-saving therapy and urgent surgery.
> - **Type 2 – T2: Can wait!**
>   This patient needs therapy and surgery, but can wait until all T1 cases are managed without danger to life.
> - **Type 3 – T3: Must wait!**
>   This is a light case, and needs simple therapy only.
> - **Type 4 – T4: Too much!**
>   This patient has injuries so extensive that surgery cannot save him, or surgery is too time consuming with the resources at hand.

Triage classification is relative

Capacity of the organization: There are no fixed rules on how specific regional injuries should be classified by triage. The actual classification depends upon the load of patients at the moment, the capacity of the clinic, and the

skills of the staff. Eg. a skilled surgeon may well manage an open thoraco-abdominal injury at a forward clinic on a quiet day (T1), whereas the same case admitted among ten mass casualties may be classified as T4.

Medical support and surgery will alter the triage classification of each patient. Eg. a penetrating abdominal injury may be a T1 case by battlefield triage, and a T2 or T3 case when packing and intestinal resection-anastomosis is done at the FC. Or a penetrating chest injury may initially be a T1 case, but classified as T2 when chest tubing and analgesia are done in the battlefield. Repeated triage should therefore be done at each level of the medical network and written in each Injury Chart by paramedics in the battlefield, on arrival at the FC, leaving the FC, at arrival at the SLC.

ıjury Chart: p. 52.

Complications may arise during the evacuation, the medical support may be insufficient or a missed injury may cause problems. Eg. a multiple-shrapnel injury is initially diagnosed as "superficial" (T3), but peritonitis develops the next day making it a T1 case. Therefore triage is not done by simply reading the Injury Chart; triage throughout the medical network is based upon repeated and exact physical examinations of each patient by the most experienced staff member present.

.epeated triage during the vacuation!

At a forward clinic you will expect a distribution after triage approximately like this:

Table 2

Triage type	**% of total**
T1	10-20
T2	20-30
T3	50-60
T4	10

Table 3
Guidelines, not rules, for triage

Clinical signs	**Type of injury**
Consider as T1:	
Airway obstruction	Head and neck injuries with obstruction
	Airway burns
	Aspiration of vomit/blood
Breathing problems	Penetrating and blunt chest and upper abdominal injuries with respiratory distress
Circulatory shock	Any injury with heavy bleeding not under control
	Pelvic and multiple major fractures
	Burns more than 30%
	Extensive soft tissue crush injuries
	Poor general condition
	More than one serious (T2) injury in one patient
	Serious (T2) injury in a patient weak from chronic illness or starvation

Clinical signs	Type of injury
(T1 continued)	Serious (T2) injuries late for treatment (signs of serious infection) Serious (T2) injuries in small children Penetrating chemical burns Closed head injuries in need of decompression
Consider as T2: No respiratory problems Stable circulatory state	Penetrating chest and upper abdominal injuries High-pressure blast wave injuries Penetrating abdominal and pelvic injury Fractures (open and closed) Burns less than 30% Vascular injuries under control but in need of vascular reconstruction Semi- or unconsciousness
Consider as T3: Moderate and light injuries	Injuries for minor debridements and dressing Face injuries for debridement and primary suture Eye injuries Minor fracture cases Blast wave injuries for observation
Consider as T4: Very extensive injuries	Head injuries with clinical signs of brain death Multiple T1 injuries in one patient Large open thoraco-abdominal lesions Serious injuries with multiple organ failure

Use the Vital Function Index for exact classification of injury severity: p. 700.

Two lessons to draw

- In four out of five war casualties you are in no hurry. The medical support and the transport should be done smoothly.
- Three out of five war casualties are well managed with simple surgical procedures and general surgical instruments. Better concentrate on performing these procedures well before preparing for advanced surgery.

Triage in mass casualties

ecovery position: p. 137.

The first round: Triage, free airways and monitoring
When you arrive, make a round and examine all patients, maximum one minute on each. **Notice:** The silent cases with few obvious signs of injury may be the most seriously injured. In this first round concentrate on free airways, perform or order the necessary airway procedures. Place all patients in recovery position. Order one person to monitor each patient; he should report to you directly and immediately in case of complications. If you have qualified assistants, let them set up double i.v. lines and start flush infusions on all cases with cool limbs (for adults, 3000 ml Ringer). Do not waste time on BP measurements.

asic life support: p. 129.

Revise your triage
- **Select the T1 cases:** Look around and select the patients that you have a reasonable chance to save by active basic life support. They are the T1 cases, concentrate on them.
- **Select the T4 cases:** Patients in grave circulatory shock within 30 minutes after the injury, patients who already sustained circulatory shock for 30 minutes without volume therapy, patients with poor spontaneous breathing and central cyanosis. Their chance of survival is less than 50% even with the best supportive therapy.

IB ventilation: p. 141.

The second round
Check that airways are still free, select cases in need of chest tube or assisted SIB ventilation. Then concentrate on volume therapy: Assess the effect of the flush infusions running.

Documentation and evacuation
Do not forget to fill in the Injury Charts even if the setting is chaotic. In mass casualties exact documentation is essential. Select assistants to follow the T1 cases, and start the evacuation. T1 cases should not go alone, if necessary leave the T4 cases without monitoring.

Points to note – Chapter 7

The airways have first priority. Everybody should train in
- head-tilt and jaw-thrust maneuver in children and adults: p. 136
- using the oral airway in children and adults: p. 136
- using naso-gastric tubing to empty the stomach: p. 139
- endotracheal intubation in children and adults: p. 137

Know when and how to support the breathing
- note the critical signs: p. 140 and 141
- train rescue breathing in children and adults: p. 141
- train in SIB-assisted ventilation: p. 141
- study when and how to insert a chest tube. Train in tube insertion guided by experienced staff: p. 142
- pain causes poor breathing. Know the i.v. doses and side effects of the main analgesics: p. 142 and 151

Train to control external bleeding by
- compressive dressing: p. 144 Note why tourniquets should not be used: p. 145
- compression or clamping of the artery proximal to the wound: p. 144. Study the anatomy to know where to compress the main limb arteries: p. 114, Chapter 38, and Chapter 39.

Internal bleeding is controlled by basic life-saving surgery
- know how to identify the patients who need emergency surgery: p. 130 and 132
- train in emergency laparotomy and abdominal gauze packing guided by experienced staff: p. 155

Train in volume therapy
- learn to assess the amount of blood lost: p. 108 and 148. Know the objectives of volume therapy: p. 147
- know when to use Ringer, and how much: p. 148. When to use plasma expander, and how much: p. 148
- study emergency blood transfusions with O-negative blood: p. 269. Learn how to do autotransfusion: p. 270.
- train to do venous cut-down: p. 146.

Prevent hypothermia
- study the physiological effects of hypothermia: p. 131 and 276
- know the methods of central warming: p. 153 and 277

7 BLS: Basic life support and basic life-saving surgery

Fundamentals of basic life-saving surgery

An effective basic life support program is the single most important factor of war casualty management. By skilled and forward management the total death rate is reduced by 10-20%.

Basic life support: Procedures to maintain the vital functions of the body. Or to restore them if injury made them weak.

The vital functions of the body: (1) Oxygenation of the blood, and (2) blood flow through the central organs of the body.

The basic life support procedures

- A – Airway: Maintain or restore free airway
- B – Breathing: Maintain or restore normal respiration
- C – Circulation: Maintain or restore the normal circulating blood volume and normal action of the heart
- Analgesia: Effective management of pain and fear

Basic life support includes forward surgery: In the unstable and bleeding multi-injury patient, vital functions cannot be maintained or restored without surgery.

The procedures of basic life-saving surgery include

- A – Airway: Reduction of displaced face fractures. Emergency laryngotomy
- B – Breathing: Insertion of chest tube
- C – Circulation: Emergency thoracotomy with compression/clamping of the aorta. Emergency laparotomy with packing of the abdomen, temporary abdominal closure, and second-look laparotomy when the patient is stable

Emergency thoracotomy: p. 154.
Emergency laparotomy: p. 155.

Preserve the body temperature: Under hypothermia, the coagulation system does not respond with clotting, and the bleeding vessels do not contract. The best body temperature for clotting and vascular response is 38 degr. C:

- Prevent loss of temperature during the evacuation
- Start early central warming in cases with extensive wounds
- Massive volume therapy with cold infusions (infusion temperatures less than 37 degr. C may increase internal bleeding)

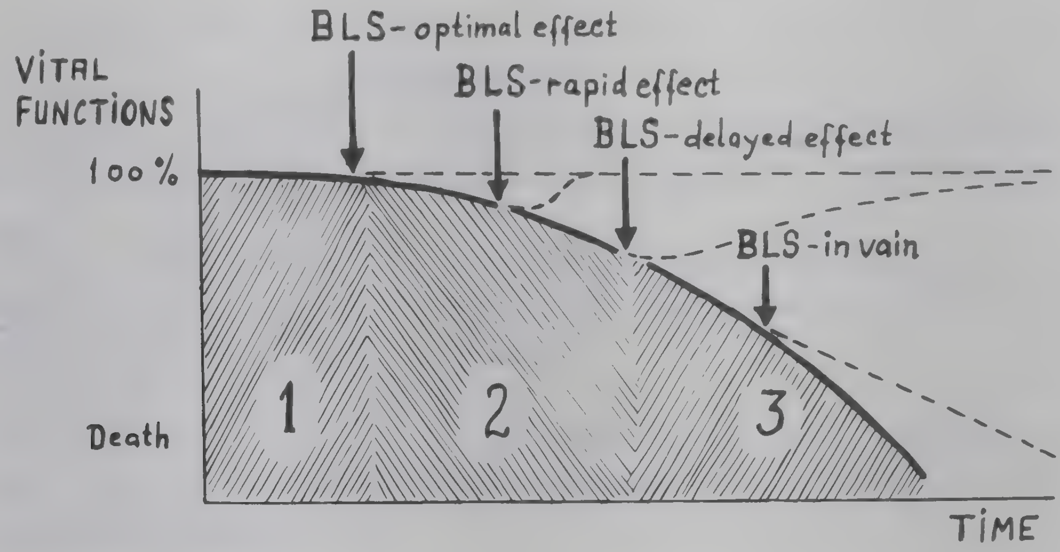
Methods for central warming: p. 153.

The triad of basic life-saving surgery:

- To prevent hypothermia, laparotomies should not last more than one hour in severely bleeding cases
- Central warming should be done before, during, and after surgery
- Prevent hemodilution: Use autotransfusion

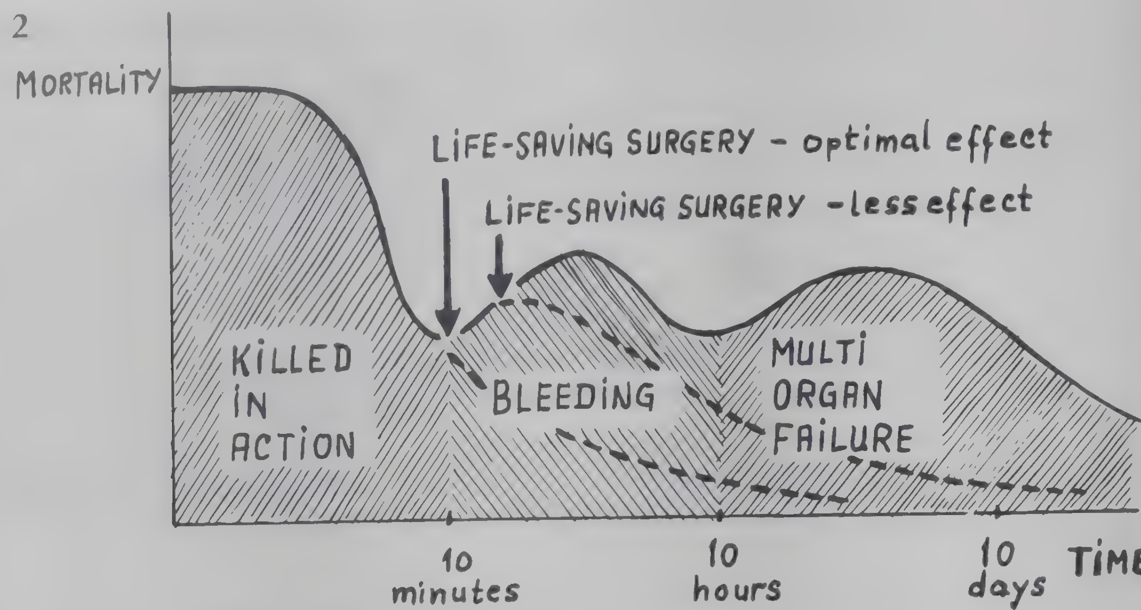
Autotransfusion: p. 270.

1



1 Start early basic life support: Severe injuries start a chain reaction of complications (study Chapter 4). Blood acidosis and hypothermia are important factors that accelerate the development of complications. Blood acidosis is the result of poor oxygenation of the blood – hypoxemia. The reasons may be airway obstruction, poor respiration and blood loss. Loss of temperature through wide wounds, massive infusions of fluids of less than 37 degr. C, and protracted primary surgery will rapidly make the body temperature fall. Acidosis and hypothermia change the vascular response to bleeding: Small vessels lose the ability to respond with contraction when blood volume is lost. Also as the response of the blood platelets and other clotting factors become weak, blood clots do not form at bleeding points – the cold patient bleeds "from everywhere". There seems to be a limit approximately of pH 7.2 and core temperature 34 degr. C below which the coagulation system collapses. **See illustration 1 – phase 1:** The best basic life support prevents acidosis and hypothermia, and thus maintains the vital functions. **Phase 2:** It is still possible to restore the vital functions. But the response to basic life support and surgery is gradually more delayed due to decreasing response from the vascular and coagulation system. **Phase 3:** The patient has acidosis and is cold. Even assisted ventilation, oxygenation, transfusions of warm blood and platelets cannot restore the circulation: Basic life support only delays death.

2



2 Mortality due to bleeding: The objective of basic life support is to maintain the blood flow (perfusion) through the central organs. Hypoperfusion causes increasing necrosis of the injured organs, and increases the risk of septicemia and secondary organ failure. The longer the time of hypoperfusion, the higher is the risk of secondary multi-organ failure. Patients dying after war injuries can be divided into three groups:

- **Killed in action:** Patients dying within minutes following major injuries to vital organs. The best forward surgery cannot save them.
- **Dying within hours:** Patients in circulatory shock which cannot be controlled by non-surgical methods. The most common cases are patients bleeding from multiple fractures, and major bleeding injuries to the chest and abdomen. Immediate surgery is the necessary basic life support.
- **Dying within days:** Patients dying from infection, septicemia and late multi-organ injury.

Notice: Children compensate well for bleeding until a certain point, when the circulation suddenly collapses if bleeding continues. Thus look for very early signs of circulatory shock. If there are increasingly unstable vital signs, do surgery immediately under ketamine anesthesia. Do not let time-consuming anesthetic procedures delay you.

After abdominal injury the mortality of the second group (death from bleeding within hours) is approximately equal to the mortality of the third group (death from sepsis and multi-organ failure after 5-15 days). Early control of bleeding followed by transfusions of fresh whole blood (platelets) and rewarming to 38 degr. C reduce the mortality in both the second group (bleeding) and the third group (organ failure). The most important factor for survival is the time-lag from injury to life-saving surgery. When the body temperature is already low due to massive volumes of cold infusions, the coagulation failure is established – and the best surgery is often in vain.

Levels of circulatory shock – clinical signs: p. 148.

The target of forward basic life-saving surgery is the unstable patient.

This is an unstable patient:

- He is in constant need for transfusion to maintain a systolic blood pressure above 80 mm Hg.
- The respiration becomes poorer despite free airways.

Static or dynamic strategy

The static strategy – not recommended

The traditional management strategy for injury cases is static – it follows the same pattern, regardless of whether the case is moderate or a multi-organ injury:

- Surgery is done in base clinics, forward field surgery is not done.
- The forward basic life support is non-surgical and consists of assisted ventilation and massive infusions of cold fluids.
- The primary surgery is often delayed.
- The objectives of the primary surgery are to restore the vital functions **and** to solve local problems, repair the injured organs as well – regardless of the severity of the injury.

The dynamic strategy – recommended

Find out what is actually the most urgent need of the patient:

- Urgent surgery to save his life?
- Surgery to avoid complications such as septicemia and organ failure?
- Or is the objective of the operation to solve a local problem, to restore as good as possible the function of an injured limb or organ?

> **Dynamic approach – make continual exact risk assessments:**
> Continually find out what is at stake in this particular situation, at this stage, in this particular patient.

The dynamic versus the traditional and static strategy

Our objective is to help the unstable patient to survive three risk periods. The dynamic response is three-step management:

- **Step one:** The main early threat to the life of the critically injured is respiratory and circulatory collapse. When that threat cannot be eliminated by non-surgical basic life support, basic life-saving surgery is done in the field: chest tube inserted, internal bleeding controlled by clamping of bleeding vessels and packing of the abdomen. Autotransfusion and active rewarming is started. Operations lasting more than one hour cause hypothermia. As the main threat in this period is **not** peritonitis or infection – elaborate debridements, enterostomies or organ repair would be destructive. Those procedures would prolong the operation time, and increase the risk of hypothermia and fatal bleeding.
- **Step two:** If the circulation is restored and the patient survives the first 24 hours, the main threat is wound infection and peritonitis. Our response is re-operation 24-72 hours after the injury on a stable patient. Then we can debride the wounds, repair the intestines, divert the fecal stream, and drain the injured organs.
- **Step three:** If the patient is still stable after the second-step operation, the main threats are pneumonia, septicemia and secondary organ failure. Our response is primarily preventive: effective analgesia, respiratory exercises, early ambulation, high-energy nutrition and mental support. And also surgical: early identification and reoperations to evacuate infections and abscesses.

Compare with a static strategy that does not make exact risk considerations:

- Step one: Primary surgery is delayed, the patient is in circulatory shock and probably cold on admission to the clinic. Attempts at vascular reconstructions and intestinal resection-anastomosis are done, diversion enterostomies are established, other abdominal organs repaired. Efforts to warm the patient during the surgery are spoiled by the prolonged operation time: Even in hot climate, the heat loss is great through a laparotomy incision. The vital signs will worsen during surgery, and further deteriorate within the next 24 hours.
- Step two: If the patient survives primary surgery, the chain reaction of complications is already activated. Persistent hypoperfusion increases the risk of wound infections and septicemia – even if the primary debridements were properly done. Reoperations in this period – to control rebleeding or resect necrotic tissue – carry high risk of circulatory collapse. And will probably add to the problems.
- Step three: Even the best supportive therapy cannot reduce the high risk of wound rupture, wound infection, peritonitis, septicemia and secondary organ failure. Further surgery is often more destructive than therapeutic.

The physiology of post-operative organ failure: p. 96.

Basic life-saving surgery – some controversial points

Compared to traditional surgical teaching, some methods of basic life-saving surgery may seem controversial:

- "Surgery in the field cannot be sterile": Correct. But the matter of sterility is of secondary interest in an unstable case that does not respond to volume therapy. He will die within hours unless surgery is done. During the first-step surgery fecal leak or instrument sterility can be ignored. Restoration of the central organ blood flow has overall priority.
- "Definitive surgery cannot be done during one hour": Correct. That is why organ repair is abandoned during the first step of basic life-saving surgery. And untraditional methods are used to shorten the operation time: Ligatures and reconstructions are reduced to a minimum. The bleeding sites are controlled with tampons of large gauze packs which are left in place until the second-step surgery. The abdomen is temporarily closed by towel clips, or interposition of plastic sheets (split infusion bags) if there is abdominal distention.
- "We need the surgeons in the main clinics": Correct. That is why we train paramedics in the procedures of forward basic life-saving surgery.
- "It is irresponsible to let non-surgeons do advanced surgery": Not correct – knowledge and training are not the privilege of surgeons. It is our experience that experienced paramedics after proper training can do chest drainage, emergency laparotomies and autotransfusion just as well as hospital surgeons.
- "There is no anesthesia service to support the field surgery": Not correct. The anesthesia for basic and urgent life-saving surgery is not a question of central i.v. lines or advanced monitoring equipment – the patient may die while those facilities are being arranged. The surgical procedures are done under intermittent i.v. ketamine anesthesia. The two factors to monitor are (1) the airways and respiration which is monitored by any paramedic trained in basic anesthesia. And (2) the central organ blood flow which is monitored by the paramedic doing surgery to restore it.

BLS — **Basic life-saving surgery** / **Basic life support**

The separation of responsibilities: Basic life support for the anesthesia side and surgery for the surgeons belong to elective hospital surgery. Basic life-saving surgery is a necessary part of the total basic life support program. Without which the vital functions in major injury cases can neither be maintained nor restored.

Transfer knowledge and the simple equipment needed to the villages and combat areas:
All procedures listed in this chapter are field procedures: They should be done there and then, as soon as possible after the time of injury.
- Train civilian health workers, ordinary villagers and soldiers in the main basic life support procedures.
- Train the clinic paramedics to adopt a dynamic approach to injuries. And train them in basic life-saving surgery.

Free airway

Equipment needed
- Oral airways (small, medium and large)
- Suction and suction tubes
- Laryngoscope (short, medium and large blades)
- Endotracheal tubes (set of 4-6 sizes), flexible stylet, one syringe (to inflate the cuff). The tubes are made of plastic or rubber. The plastic tubes become soft and will bend in very hot climate
- Naso-gastric tubes
- One small debridement set. Non-absorbable suture (1-0)
- Syringes. Cannulas. Lidocaine 0.5% and 2%.

The essentials of free airway management
- Open the upper airways by the head-tilt and jaw-thrust maneuver
- Secure free airway by airway tube or endotracheal intubation
- Reduce the risk of aspiration by recovery position, gastric decompression, cricoid pressure

Critical signs

- **"Snoring" respiration.** The tongue slips backwards and blocks the airway. Risk cases: Patient is drowsy, extremely exhausted or in coma. Head injuries. Hypothermia. Circulatory shock.
- **Blocking of the upper airways.** Risk cases: Midface fractures displaced backwards. Upper airway burns. Blunt or penetrating neck injuries (deep hematomas and edema may obstruct the airways).
- **Bleeding into the airways.** Risk cases: Extensive face and neck injuries.
- **Aspiration.** Risk cases: Abdominal distention after abdominal injury or surgery. Head injuries. Circulatory shock.
- **Cyanosis.** Urgent action! Open airways and support the breathing immediately!

Measures
– step one: Open the airway

Head injury: The most important BLS is free airway.

- Place the patient supine on a flat surface. Remove pillows.
- Clear mouth and pharynx with your finger. At the same time explore if there are wounds or fractures.
- Clear the upper airways by suction.

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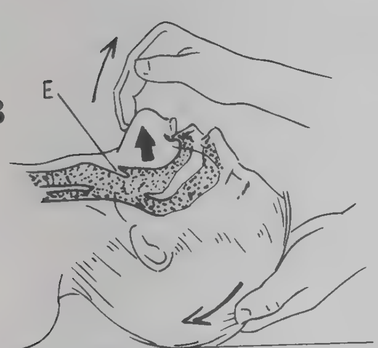

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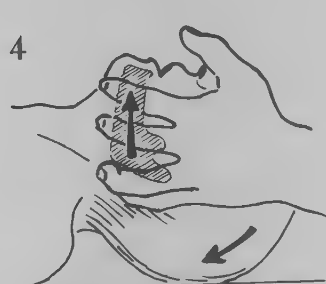

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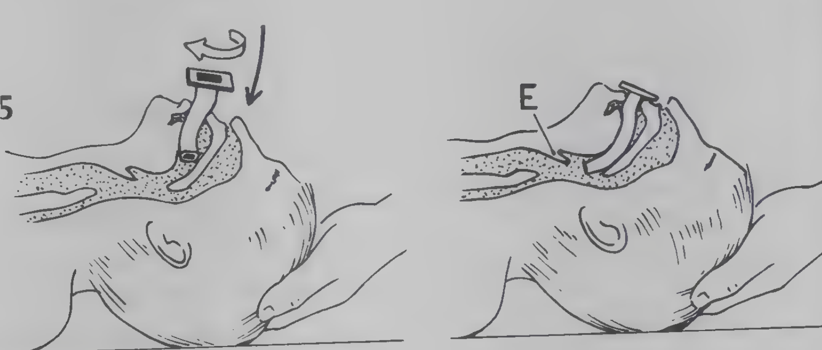


3, 4 • **Head-tilt and jaw-thrust:** Extend his neck and lift his jaw forwards – watch out for unstable cervical spinal injury. This maneuver prevents the tongue and epiglottis (E) from obstructing the airway. The head is still tilted. Now thrust the jaw forwards by the 4th and 5th fingers of both hands. Stabilize the head-tilt with the other fingers and the palms. By this maneuver the tongue is lifted forwards.

5 • **Insert an oral airway:** It prevents the tongue from slipping backwards, and should be used during evacuation and assisted ventilation. Let the oral airway pass into the mouth with its tip pointing upwards towards the palate, or else the tube will press the tongue backwards. Then rotate the airway into his pharynx. Suction at intervals through the oral airway. **Notice:** If the airway is too small, it pushes the tongue backwards and causes obstruction. If it is too large, it may bend epiglottis backwards and cause obstruction. **If the tongue still blocks the airway or if you have no oral airway,** fix the tongue in a forward position by suturing its tip to the skin of the lower lip.

6 • **Recovery position:** This is the routine position to prevent aspiration of blood and vomit during evacuation.

If step-one measures do not secure a free airway, proceed to step two: Endotracheal intubation

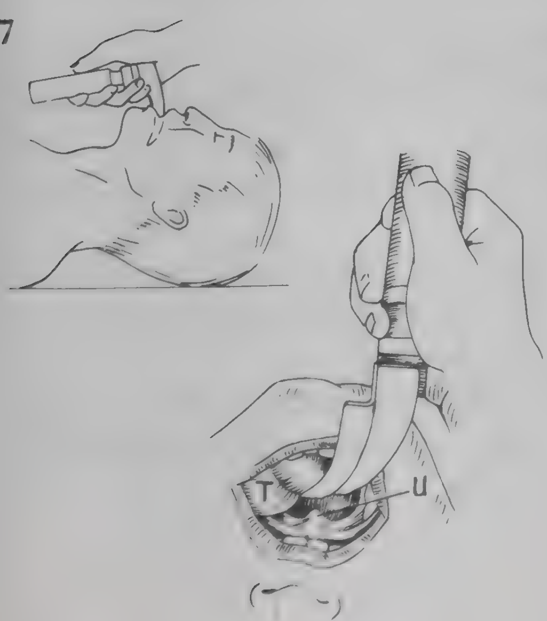
Cases that need endotracheal intubation
- Patients in coma or semi-coma after head/neck injury
- Patients with insufficient spontaneous respiration
- Extensive face injuries
- Multiple-injury patients
- All other cases where you cannot secure free airway by the step-one procedures.

Table 1

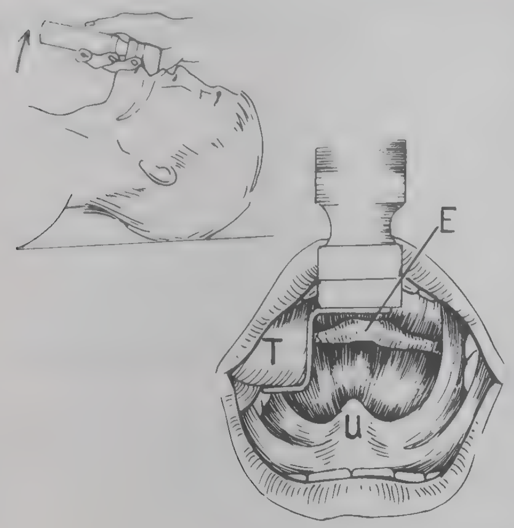
Tube size (diameter in mm)	Age of patient
3. 0	Newborn
3. 5	6 months
4	2 years
4	3 years
5	5 years
6	8 years
7	16 years
6-8	Adult females
8-10	Adult males

Try to make the intubation within 30 seconds, or else the patient becomes hypoxic. Ventilate him well (MTM or mask-and-SIB) for 1-2 minutes before the intubation.

7



7 **The intubation procedure – retract the tongue. (If you are right-handed, keep the laryngoscope in your left hand and insert the tube with your right hand. For reasons of illustration these drawings show a left-handed intubation.)** Place the patient in a bed or on a table. Intubation lying on the ground is difficult. In broad daylight you cannot see the light of your laryngoscope: Put a blanket etc. over yourself and the patient. First tilt his head (p. 136), insert the laryngoscope halfway and lift the tongue (T) up and aside. You can now see the uvula (U) and the posterior wall of the pharynx.

8


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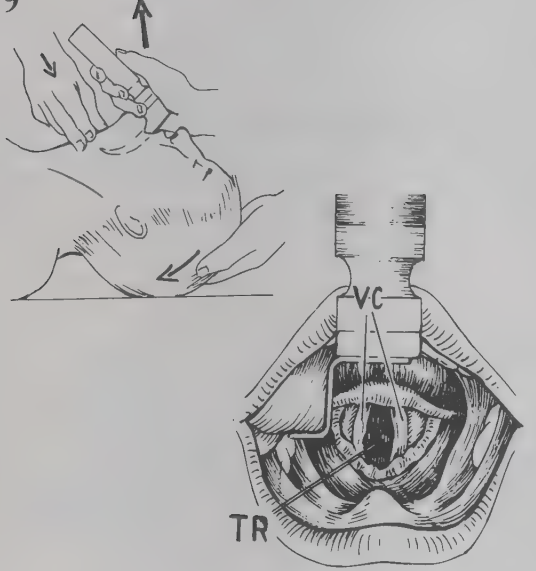


8 Identify epiglottis: Let the blade of the laryngoscope slide towards the base of his tongue. In this position you can see the epiglottis (E) and the inlet to his larynx. Do not insert the tube yet! You have to see the vocal chords before intubation.

9 Identify the vocal chords: Extend his neck. Lift upwards with the laryngoscope, but do not lift the epiglottis. Now you can see his vocal chords (VC) and the inlet to his trachea (TR). If the view of the tracheal inlet is not complete, ask your assistant to press slightly upon the larynx from outside. Pass the tube down between the vocal chords under continuous vision. Never force the tube! You may permanently damage his vocal chords, or create local wounds, edema and obstruction of the larynx. With the tube in position inside trachea, inflate the tube cuff. Steady the tube firmly until you have checked the tube position and secured it with adhesive tape.

Check the tube position: Blow air through the tube by mouth and check with your stethoscope that you can hear respiratory sounds over both lungs. Also check that there are no respiratory sounds over the stomach (esophageal intubation). If the respiratory sounds are weak on one lung, the tube is probably in a too distal position: Withdraw it 1-2 cm and recheck. **Fix the tube well** by adhesive plaster to the cheek. **Recheck the tube position again! Suction of the lower airways** is done through the tube with a soft plastic tube (suction catheter or naso-gastric tube). If you have no suction, use a 50 ml syringe.

Intubation with stylet

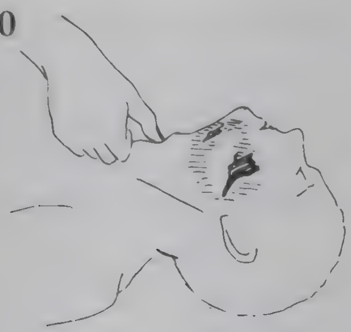
In some patients the anatomy is such that the larynx inlet cannot be fully exposed by the standard procedure. Insert a curved flexible stylet/introducer into the tube, get the best possible view of the vocal chords, and insert carefully the tube with the stylet. When the trachea is entered, remove the introducer and forward the tube to the correct position.

Intubation in conscious patients

If the patient is awake but still needs intubation (extensive face/jaw/neck injuries), perform conscious intubation. His cough reflex must be reduced before intubation:

- Sedate him with 5 mg morphine i.v. before the intubation.
- Open his mouth with your finger and spray some lidocaine 2% on his tongue and tongue base.
- Retract his tongue with the laryngoscope blade and spray lidocaine on his epiglottis and pharynx.
- Pull the laryngoscope until you see his vocal cords and spray the rest of lidocaine down on the cords and upper trachea. **Or** inject lidocaine 2% through the crico-thyroid membrane (ill. 10) into the trachea.
- Now perform the ordinary intubation. He will probably cough a little when the tube is applied. Reassure him that he will soon tolerate the tube well.

10



10 Failed intubation – laryngotomy: If bleeding, bone fragments or foreign bodies make endotracheal intubation impossible, and the patient has central cyanosis – laryngotomy is life saving. This is an emergency procedure to be done at the site of injury, without anesthesia, with any sharp knife at hand. Three large-caliber cannulas will also make an artificial airway. Standard tracheostomy is time consuming, and has no place in emergency management of airway obstruction.

Identify the crest of the thyroid cartilage (T). Just below it you can feel the peak of the cricoid cartilage with your finger. Between them is the crico-thyroid membrane which is the place for laryngotomy. Make a small longitudinal skin incision exactly in the midline. Retract the soft tissues with your finger. Feel the membrane and open it transversely. Insert one finger or the handle of a scalpel knife into the larynx to secure inlet of air. Then guide an endotracheal tube through the incision.

Effects of endotracheal intubation

- Guaranteed free airway, no possibility of aspiration.
- You may clean the lower airways with suction through the tube.
- Assisted ventilation with a self-inflating bag is simple.
- You may give adrenaline, atropine and lidocaine through the tube: Double the standard i.v. dose and dilute to 10 ml with normal saline.
- You may hyperventilate head injuries: Hyperventilation is the single most effective measure in brain edema.

Under difficult and lengthy evacuations no procedure other than intubation can continuously secure free airway. Better train your paramedics in the art of rapid and safe intubation. Skilled intubation is not a question of much theoretical knowledge; it is a question of training. Train them well.

11

2

Measures – step three: Supportive procedures

11, 12 Abdominal decompression – naso-gastric tube: All abdominal cases should have a naso-gastric tube inserted before evacuation starts. Decompression reduces the risk of vomit-aspiration, and promotes the breathing. Before introducing the tube, make a mark 60 cm from its end. The length 60 cm is the mean distance from his teeth to his stomach (adult). Introduction is more safe and easy when the patient is sitting. Moisten the tube and introduce it through one nostril along the floor of the nose directed towards his ear. When the tube reaches his pharynx, tell him to swallow. Or give him some water and introduce the tube smoothly down his esophagus exactly when he swallows. **Notice:** Coughing is a sign of introduction into the airways: Withdraw the tube and try again. You may bend his head slightly forwards to ease the introduction into the esophagus. **Notice:** Weak patients may not cough even if the tube enters the airways. With your ear against the tube end you will hear his respiration if the tube enters the larynx.

When the tube is introduced 60 cm from the nostril, inject air with a syringe and listen over his stomach. Angulation of the tube inside the esophagus or inside his stomach may cause tube obstruction; withdraw the tube and reintroduce it. Fix the tube well with adhesive tape to his face. Aspirate air and gastric fluid with a 50-ml syringe. Blood from the stomach? Fix the tube well.

Anti-emetic: Metoclopramide 10-20 mg i.v. (adults). Consider metoclopramide during rough evacuations when morphine is used for analgesia .

Prevent aspiration – cricoid pressure: Without an endotracheal tube you can prevent aspiration by pressing the cricoid cartilage backwards and thus block the esophagus. The cricoid itself can resist considerable pressure without obstructing the airway. With risk of aspiration cricoid pressure should be continuously maintained during the evacuation.

Support the breathing. Chest drainage

Equipment needed
- Airways – small, medium and large
- Face masks – small, medium and large
- SIB or self-inflating bag (Laerdal, Ambu or some copy)
- Chest tubes (diameter 9-11 mm). Small debridement set. Suture materials. Local anesthetics
- Analgesics

Also see BLS kits: p. 64.

The essentials of respiratory support
- Central cyanosis: Start immediate rescue breathing
- Effective analgesia
- Assisted ventilation with SIB
- Early chest tube insertion
- Gastric decompression

Critical signs – 1

- **Central cyanosis:** The lips and mouth mucosa are bluish, the skin and nail beds blue or greyish. There is a grave lack of blood oxygen.
- **Irregular or no respiration:** The risk cases are head injuries, hypothermic patients and blast wave injuries.

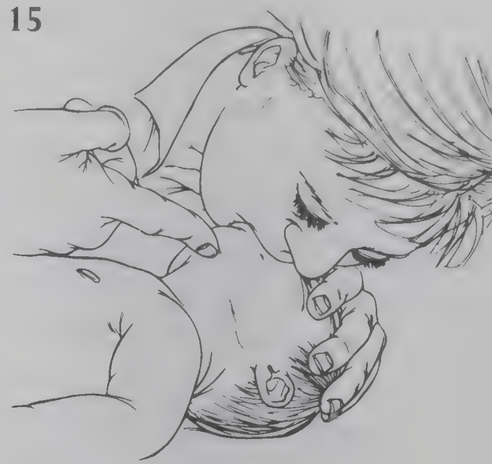
Measures – 1: Assisted ventilation

Without intubation – rescue breathing: The expired air from the rescuer contains enough oxygen (16%) to supply the patient. The airway is opened by the head-tilt and jaw-lift maneuver (p. 136), and the rescuer gives breaths through the patient's mouth, through the nose or through both. The frequency should be one breath every 5-6 seconds. The rescue breath is like inflating a balloon; do not breath too rapidly and forcefully as that may inflate the stomach of the patient with risk of aspiration. To increase the oxygen content, the rescuer should take one breath on his own between each rescue breath.

3

14

15



3 **Mouth-to-mouth:** Head-tilt nd jaw-lift, close the patient's nose y the right-hand pinch and seal your outh tightly around the patient's outh. Give the rescue breath while oking at the chest to see if it rises uring each breath. If the chest does ot rise, increase the breath volume. Iaintain the head-tilt position and emove your mouth after each breath o see the chest fall and hear that the ir is let out.

14 **Mouth-to-nose:** Use this method in lower face injuries and also if you are not able to seal the mouth-to-mouth way tightly. Note that the most common cause for the chest not to rise is airway obstruction: Improve the head-tilt and jaw-lift position.

15 **Rescue breathing in children:** Seal your mouth around the child's **mouth and nose.** As airway resistance in children is higher, it may be necessary to increase the force of each rescue breath. The correct force and volume are that which makes the chest rise.

6

16 **Without intubation – SIB ventilation on a face mask:** Head-tilt and insert an oral airway. One hand holds the face mask **and** maintains the head-tilt and jaw-thrust position. Note the 4th and 5th fingers pushing the jaw upwards/forwards. Work the bag with the other hand. The standard ventilation frequency is one blow every 3-4 seconds. The expiration time (between each bag compression) should be twice the inspiration time. If the patient has some spontaneous ventilation, adjust the bagging to his respiratory frequency. Watch the chest rise and see that the abdomen does not to become distended. If there is risk of aspiration, let one assistant do the cricoid-pressure maneuver while you make the ventilation. Give frequent and smaller breaths so as not to inflate the stomach. **Notice:** Bagging on the mask is not simple; you will need a lot of training to both seal the mask and maintain free airway.

Endotracheal intubation and SIB ventilation

First, give effective assisted ventilation by rescue breathing or SIB ventilation on a face mask for 1-2 minutes. Then perform endotracheal intubation, connect the SIB and continue assisted ventilation.

Critical signs – 2

Superficial rapid respiration. There may be several reasons for it:

- Pain and/or fear
- Hemo/pneumothorax
- Chest wall injury
- Abdominal injury with a distended stomach

Measures – 2

Half-sitting position will improve his ventilation.

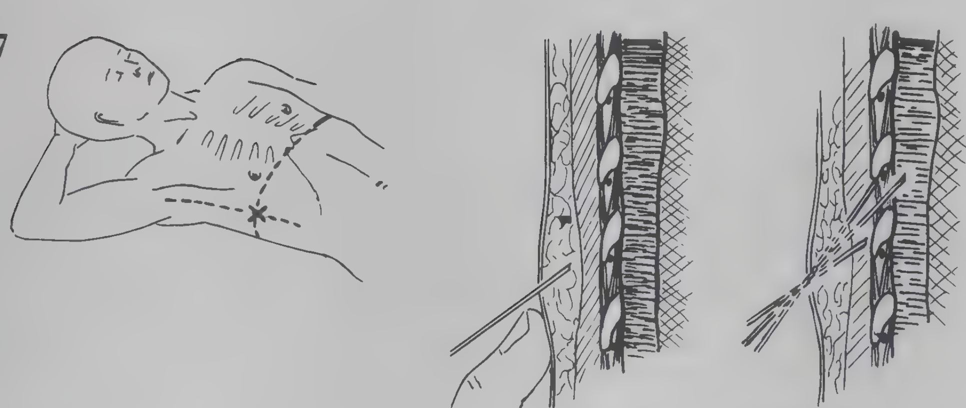
The old dogma – "morphine depresses respiration" – is not true. Repeated i.v. standard doses of morphine stimulate the respiration: The big respiratory depressant is pain!

Analgesia – alternatives (adult dose):
- Morphine i.v. 5-10 mg
- Buprenorphine i.v. 0.3-0.6 mg
- Pentazocine i.v. 30-60 mg
- Ketamine i.v. 25-50 mg
- Add diazepam i.v. 5 mg for anxiety or unrest.
- Pleural anesthesia through the chest tube is effective analgesia. Lidocaine 20 mg diluted with NaCl to 20-40 ml is flushed through the tube into the pleural space. The tube is clamped for five minutes.
- Intercostal nerve block (p. 673) is an alternative to pleural anesthesia. It may be indicated in chest wall injuries, multiple rib fractures and high abdominal injuries.

Chest tube

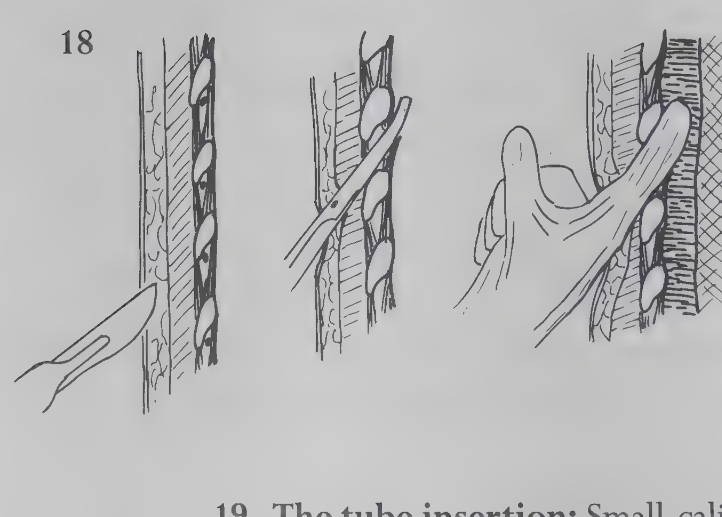
All penetrating chest injuries with hemo/pneumothorax should have chest tube inserted as soon as possible after the time of injury. Early clinical diagnosis may be difficult: Patients with "possible hemothorax" should also have chest tube inserted.

17



17 The site for insertion: below the 6th rib in the mid-axillary line. Infiltrate lidocaine 0.5% in skin, muscle and pleura. To identify the intercostal space, first identify the rib with the needle. Then "walk" the needle upwards to the intercostal space.

18

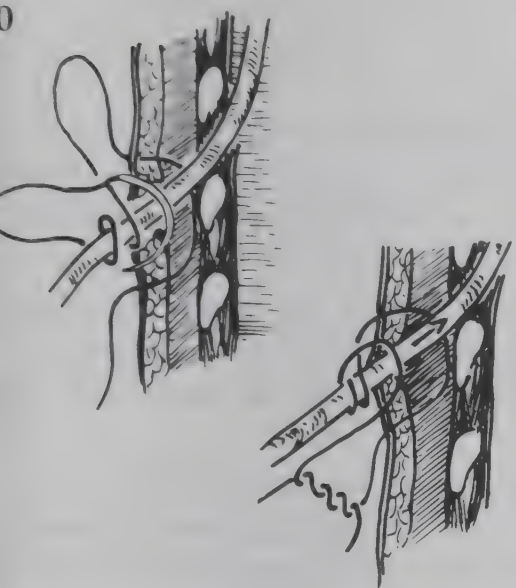


18 The incision: Incise the skin with a knife blade. Direct the tube track through the chest wall obliquely upwards. Tunnel a channel through the chest wall with a large hemostatic forceps or scissors. Let your finger follow the tunnel through the pleura to check that you have entered free pleural space.

19

19 The tube insertion: Small-caliber tubes will clot. The adult tube diameter should at least be 10 mm (see conversion table p. 143). Make some side holes in the tube if there are none. Close the outer part of the tube with a clamp. Grasp the tube end with the forceps and drive the tube firmly through the tunnel and 10-15 cm into the pleural space.

0



20 The tube fixation: Let the assistant fix the tube by hand until you have arranged the sutures. For two reasons we advice a deep mattress 1-0 suture (large curved cutting needle) running twice around the tube: First, it fixes the tube well. Second, when you remove the tube, release the mattress suture without cutting it; remove the tube and immediately tie the suture again. The suture seals the tube track and is more air-tight than any other suture. Some leaking of air along the tube track after tube insertion and tube removal is common. After some hours wound edema will seal the leak.

Drainage by the chest tube: Connect the suction and open the tube. Note exact time and volumes drained in the Injury Chart. Then connect the chest tube to a long plastic tube that you seal underwater in a bottle of soap solution placed on the floor – dependent drainage. To promote drainage, tell the patient to ventilate deeply. Also instruct him to blow balloons (surgeon's gloves). Effective analgesia is a must (i.v. or pleural anesthesia)!

Chest wall injuries
Open injuries: When a chest tube is inserted, close the chest wall wound (p. 344). Multiple rib fractures: There is much pain and respiration is insufficient. Fracture fixation is not effective. Analgesia is the only BLS needed. Consider intercostal nerve block.

Decompression by naso-gastric tube not only prevents vomit and aspiration. It also improves the ventilation of the lower parts of his lungs. Consider using naso-gastric tube in patients with much pain, head injuries and cases in shock: They may have a "silent abdomen" with retention of gases and stomach fluid – even if they have no abdominal injury.

Medical catheter diameter conversion table

Diameter mm	English gauge	French charrière
4	6	12
5	8	15
6	10	18
7	12	21
8	14	24
9	16	27
10	18	30
11	20	33

Also see BLS kits: p. 64.

Manage circulatory shock

Equipment needed
- Gauze pads (40x40 cm)
- Gauze bands
- Elastic band (rubber or cloth)
- Small debridement set
- Fluids: Ringer lactate or Ringer acetate or NaCl 9 mg/ml
- Plasma expander
- I.v. cannulas, infusion sets, adhesive tape
- Preferably intraosseous infusion needle

The essentials of circulatory shock management
- Control ongoing bleeding
- Assess the blood volume lost
- Restore normal circulating blood volume
- Monitor continuously the effects of your therapy

Control internal bleeding

Emergency surgery

- **Chest injury:** One out of five cases with hemothorax needs thoracotomy to control bleeding. The indications for thoracotomy are drainage of 1500 ml blood on the chest tube when it is inserted, or 500 ml blood/hour for three hours. In most cases minor arteries in the chest wall are the source of the bleeding. If the clinic is far, emergency thoracotomy in the field is life saving: Debride the inlet wound. Even if you cannot identify the bleeding vessel, a tight closure of the chest wall wound track will probably control the bleeding (p. 344).
- **Abdominal injury:** The indication for emergency laparotomy is steady or increasing signs of circulatory shock despite effective and aggressive volume therapy. If the clinic is far, laparotomy in the field is life saving and should be done without hesitation: Ketamine anesthesia, no effort to identify the bleeding vessel, pack the bleeding area with large gauze packs and close the incision with some interrupted heavy sutures. Consider thoracotomy with clamping of the aorta (p. 154).
- **Head injury and circulatory shock:** The head injury itself seldom causes circulatory shock. The shock indicates that this is a multiple-injury case with internal bleeding. To maintain brain blood circulation, systolic BP 90-100 mm is necessary. If the patient does not respond with BP increase after the first flush infusions of Ringer-plasma expander, there is no wait-and-see! Do emergency surgery to control the internal bleeding.

21

22

23

Control external bleeding

21 Step one – wound compression: Press gauze packs or any cloth (the wound is dirty already) deep into the bottom of the wound as a tamponade. In deep wounds better use a long gauze band (1-2 m). It will tamponade every pocket of the wound and stop any external bleeding. Apply manual compression upon the tampon for 10 minutes while elevating the limb. During evacuation, wrap an elastic bandage for fixation. If the bleeding does not stop, proceed to step two.

22 Step two – manual compression of the proximal artery: Study the anatomy of the limb arteries to know where to compress them (p. 114). Continuous proximal artery pressure together with wound compression control most bleeding wounds. If not, proceed to step three.

23 Step three – clamping/ligature of the proximal artery: The assistant compresses the artery while you seek the artery and finger clamp it, either through a small separate incision proximal to the bleeding wound, or inside the wound track. Extend the wound in the proximal direction; a torn artery will retract. After finger clamping, apply vascular clamps (large bulldog clamps are convenient) or a sling of rubber or plastic band around the artery. Such occlusion will not permanently damage the artery, and later reconstruction is possible. In emergencies: Use any hemostatic forceps to clamp the bleeding vessel. Pack with gauze and leave the forceps inside the wound until proper surgery can be done.

Ban the tourniquet!

- It does not work: Most tourniquets obstruct the veins, not the arteries. Thus they increase the bleeding.
- It increases the tissue damage: If tourniquets are tight enough to obstruct the bleeding artery, they also occlude the collateral arteries that might save the limb. Without collaterals the limb will die within 2-3 hours.
- Most tourniquets are applied far too proximal to the bleeding level. The result is unnecessarily short amputation stumps.
- **You do not need the tourniquet:** You control any bleeding limb wound with the measures 1-3 above. Bleeding from amputation stumps is controlled by one or two elastic bands wrapped tightly from the stump upwards.

Restore the circulating blood volume

Indications for urgent volume therapy

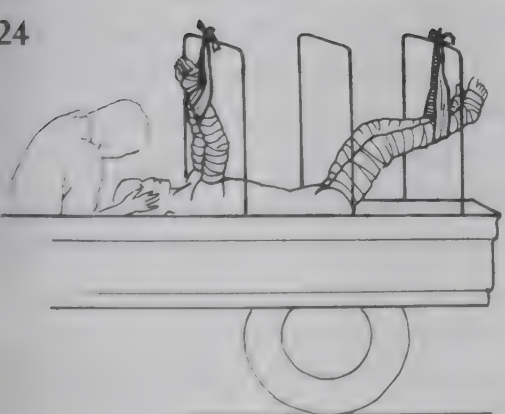
- Loss of 10% or more of the blood volume (adults: 500 ml or more)
- Burns of 20% or more of the total body surface
- Any sign of circulatory shock, regardless of how the circulating volume is lost

The procedure

- Step one: Elevate limbs. Consider "shock dressing".
- Step two: Establish two large-bore i.v. lines and flush two infusions. If you do not succeed, do immediately venous cut-down or begin intraosseous infusion.
- Step three: Assess the blood volume lost and decide the start dose of infusion.
- Step four: Monitor the effect of the start dose. Plan further volume therapy.

he normal blood volume in adults:
0 ml/kg
n small children: 85 ml/kg
ntraosseous infusion: p. 146.

24



24 **Improvised shock "dress":** By this maneuver you assist the body in shunting the blood into the central organs. First elevate the limbs for 1-2 minutes, then wrap them tightly with elastic bandages from distal to proximal. Keep the limbs elevated. "Shock dress" on four limbs shunts 1-2 liters blood into the central circulation.

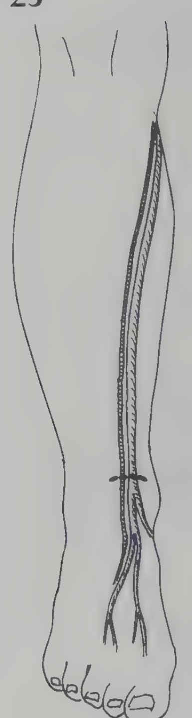
The i.v. lines

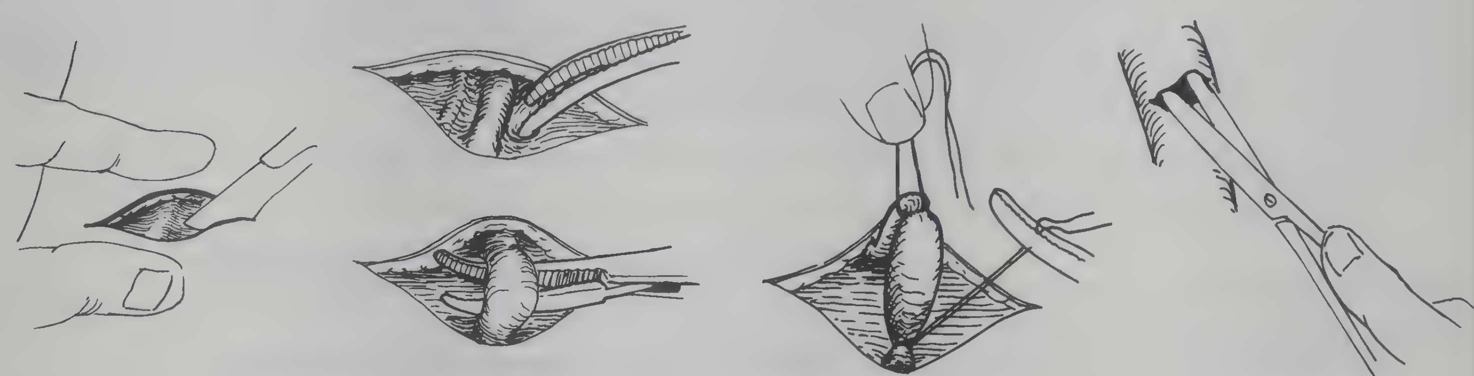
- **Large-caliber cannulas** (1.4-1.7 mm) allow higher infusion rates.
- **Any vein may be cannulated.** Also through burn wounds. Train to cannulate all of them. The lateral vein on the arm is convenient in adults. The external jugular vein is safe with good capacity. In emergencies the femoral vein may be cannulated blindly, just medial to the femoral artery pulse beat (accidental arterial cannulation is no problem).

In cold climate: Prevent freezing in the i.v. tube by taping the tube to the skin under his clothes. Or put the bag and infusion set under the patient, let his weight flush the infusion.

- **Serious cases: Establish at least two i.v. lines.** If the veins collapse and the second cannulation is difficult, the cannulated vein can take another cannula proximal to the first one.
- **No delay:** If the line does not work immediately, there is no wait-and-see – leave that cannula and go for another venous line. If the veins have collapsed and you expect cannulation to be difficult, perform venous cut-down or intraosseous infusion directly. When the shock is reversed and the veins refilled, ordinary i.v. lines may be arranged.
- **Fix the i.v. lines well:** Unrest and confusion is common in shock cases; the patients may tear the lines.

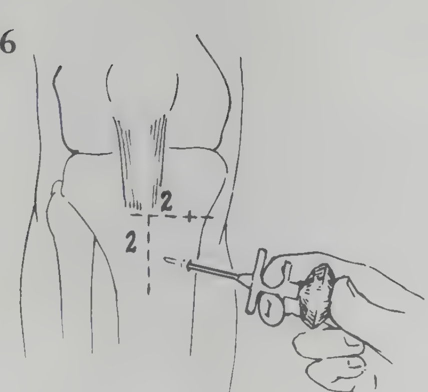
25





25 Venous cut-down – the saphenous vein: Use the standard i.v. infusion tube as a venous catheter. It is always at hand, sterile, cheap, and allows high infusion rates. Cut the tube end obliquely, also make some small side holes on the distal 10 cm of the tube. The cut-down is done in infiltration anesthesia without adrenaline. In adults the cut-down is done on the saphenous vein at ankle level. In infants the saphenous vein at groin level is used. Dissect the vein bluntly through a transverse skin incision. Note the nerve close to the vein, do not include it in the ligatures. Tie the distal ligature; but leave the proximal ligature untied. Open the vein with a small transverse incision and insert the infusion tube 15-20 cm into the vein. Tie the proximal ligature around the tube for fixation. Skin suture. **Note:** The cut-down i.v. catheter may cause thrombosis and infection. When the condition is stable insert i.v. cannulas and remove the catheter.

26



26 Intraosseous (i.o.) infusion is a good alternative to venous cut-down when the veins have collapsed. In infants where cut-down takes some time and only minor volumes of infusion are needed, i.o. infusion is efficient. Special i.o. cannulas are available, and are also reusable. They have a stylet to prevent bone plugs from obstructing the cannula during insertion. The proximal and distal parts of tibia and the condyles of femur are the best sites for i.o. infusion.

Work sterile and wash the skin well. The cannula is introduced through the bone with a twisting movement. You can feel some loss of resistance when the bone marrow is entered. Inject (there is a slight resistance) 5 ml normal saline through the cannula, then aspirate blood and marrow to confirm correct position of the cannula. Through the i.o. line you may give Ringer, NaCl, plasma expanders, blood transfusion and drugs. With pressure cuff on the infusion bag one i.o. cannula can take 2 liters/hour. You may use several i.o. canals simultaneously in adult shock management. The risk of osteomyelitis after i.o. infusion is minimal (less than 0.5%) if the cannula is removed within 24 hours.

Arrange the i.v or i.o lines before the evacuation starts. It cannot be done inside a moving off-road car.

The infusions for volume therapy

Electrolyte solutions

They are the basis of volume therapy. We advocate the Ringer solutions as the standard – even if NaCl may have some advantages in field BLS.

- **Ringer lactate/Ringer acetate** contains sodium, chloride and potassium in the same concentration as that of the body. Drawback: It clots more often in the i.v. cannulas than does normal saline.
- **NaCl 0.9% – normal saline** contains sodium and chloride in concentrations approximating the body fluids. Drawback 1: In heavy bleeding volume therapy with NaCl will cause hemodilution and hypokalemia. Severe hypokalemia may cause heart arrhythmia and reduce the heart output. Drawback 2: High volumes of NaCl infusion may cause abnormal high serum concentrations of chloride and blood acidosis.

Plasma expanding infusions

They are composed of big molecules that "suck" water by osmotic effect from the tissues into the bloodstream – thus expanding the circulating blood volume.

- **Dextran 70 (Macrodex):** I.v. infusion of 500 ml Dextran 70 expands the blood volume with the 500 ml **plus** 250 ml during the first hour after infusion. The expanding effect is reduced to 50% within 24 hours. Dextran has an antithrombotic effect. It also improves the capillary circulation, a useful side effect in trauma cases. Drawback 1: Serious allergic reactions can happen. Drawback 2: Macrodex cannot be frozen. Drawback 3: Macrodex may increase bleeding.
- **Polygelatin (Hemaccel):** I.v. infusion of 500 ml hemaccel does not expand the blood volume beyond the 500 ml of infusion. The volume effect of hemaccel is reduced to 50% within three hours. Hemaccel may freeze without being damaged. Allergic reactions are uncommon and seldom serious. Drawback 1: No expander effect. Drawback 2: Hemaccel does not have the antithrombotic effect of dextran.
- **Plasma and albumin** have no place in field BLS.

Consider emergency transfusion of O blood a part of the shock regime.

The volume therapy in adults

Children do not respond to blood loss by a decrease in BP! Look for the silent, unresponsive child with cool nose tip and some tachycardia: He may have lost more than 20% of his blood volume.

Objectives

- Restore and maintain a systolic BP more than 80 mm within 15 minutes.
- Urine production per hour 1 ml/kg/hour within 1 hour. (Infants: 10 ml/kg)
- Restore limb circulation within 30 minutes.
- Restore a hemoglobin level of 8-9 g%.

The figures listed are based on adults – 70 kg. For children, assess their body weight roughly. See table p. 261 and reduce the volume of infusions accordingly.

Start dose
– less than 20% of the blood volume is lost (less than 1 liter in an adult):
• The limbs are cool
• PR and BP are normal
→ Two i.v. lines
→ Flush 2000 ml Ringer
Monitor the effect.

Start dose
– from 20%-40% of the blood volume is lost (1-2 liters in an adult):
• The limbs are cool
• PR 100-140/min
• BP starts decreasing
→ Two i.v. lines
→ Flush 4000 ml Ringer **or** 3000 ml Ringer plus 500 ml Dextran 70
Monitor the effect: Unstable BP or steady cool limbs
→ 1000 ml O blood
→ Cross-match more blood transfusions
→ Consider emergency surgery to control bleeding

Start dose
– more than 40% of the blood volume is lost (2 liters in an adult):
• The limbs are cool
• PR > 140/min
• Systolic BP less than 80 mm
• Mental unrest and confusion
→ Flush 4000 ml Ringer and 1000 O blood (or Dextran 70)
→ Cross-match more blood transfusions
Monitor the effect: No or poor response
→ Blood transfusion. Flush more Ringer
→ Emergency surgery to control bleeding

Problems to consider

Circulatory shock, the bleeding stopped – refill slowly: Most penetrating injuries on major vessels in the chest or abdominal cavity are fatal. The patient dies within minutes, no effort can save him. But in cases where the bleeding is less dramatic, the bleeding vessel may clot and the bleeding stop spontaneously when the blood pressure falls to a certain level. Or – in abdominal and pelvic injuries – the bleeding stops spontaneously when the retroperitoneal hematoma has reached a certain size. In this case you find the patient in a degree of circulatory shock, but he does not bleed anymore. He responds well to volume therapy, but run the volume therapy carefully: Fatal rebleeding may start if his BP rapidly reaches 100-120 mm. Try to maintain a BP 80-100 mm until he is on the operating table.

Blood dilution – hypoxemia: Ringer-expander infusions dilute the blood and reduce the blood capacity to carry oxygen. Otherwise healthy young patients tolerate dilution to Hb 7 g%. Old patients and cases with chronic diseases or

malnutrition may need blood transfusion at Hb 9-10 g%. On the other hand blood dilution reduces the risk of thrombosis; hematocrit 25% is reasonable.

Dilution of blood platelets: High volumes of Ringer-expander cause bleeding tendency due to low platelet counts. "Bank blood" is poor in platelets and may add to the problem. Platelet counts less than 50 000/cubic mm make surgery difficult: Order transfusions of "fresh" whole blood.

Hypokalemia: High volumes of NaCl infusion may cause hypokalemia. Add 20 mmol KCl to every 4 liters of NaCl to prevent complications.

Hypothermia: Body temperature below 32 degr.C causes bleeding tendency and risk of cardiac complications. Even in hot climate patients with extensive injuries develop hypothermia, and cold transfusions and infusions may cause serious hypothermia. Warm the fluids and blood when aggressive volume therapy is done.

he younger the child, the higher is he risk of hypothermia after injury: . 262.

Ketamine – advantages and drawbacks: Ketamine analgesia (1mg/kg i.v.) has a pressor effect in circulatory shock: Stimulation of the sympathetic nervous system → increased blood pressure. Thus i.v. ketamine in repeated doses is the analgesic of choice during evacuation of circulatory shock cases.

On the other hand ketamine has a certain negative effect on the heart contractions (negative inotropic effect). The pressor effect dominates when ketamine is used within 6-12 hours after the time of injury. But in patients exhausted after days of evacuation, much pain, insufficient volume therapy – ketamine analgesia may cause **hypotension:** The sympathetic nervous system is "exhausted and empty" and does not respond to ketamine. In such cases the pain is the only pressor drive. When you remove the pain, the circulation may collapse. **Precaution:** Give volume therapy until veins are no longer collapsed – then start ketamine analgesia.

Unrest and confusion: When shock develops, often the patient becomes restless and gradually confused. In particular after dramatic injuries and rescue operations mental complications may cause trouble: He may tear the i.v. cannulas and oppose the management. Effective analgesia is also the best tranquilizer.

Give exact prescriptions!

During triage of mass casualties: Assess the blood volume lost, order the start doses of infusion, how fast they should run – and the exact time when the next assessment should be done, and by whom. Never leave a circulatory shock patient without monitoring and without a detailed (written) plan.

Also do the same during evacuations. An example: You find one adult trapped in a bombed house one hour after the injury. He has a crushed and fractured lower limb, you also suspect pelvic injury. His skin is pale and cool, PR 140, BP 80. You assess his blood loss to be at least 2 liters. After 20 minutes, ketamine analgesia and flush infusions of 4000 ml Ringer plus 1000 ml Dextran 70, and ketamine analgesia he improves: The skin is warmer, the veins filled, PR 110, BP 100 and he produces urine (bladder catheter). The evacuation time to the clinic will be three hours, and you suspect bleeding inside his

pelvic cavity. This is your prescription (written on a sheet of paper/Injury Chart attached to his body, or with a marker pen on his skin):

6 a.m:	Time of injury
7 a.m:	PR 140, BP 90, ketamine 50 mg i.v., Ringer 4000 ml, Macrodex 1000 ml
7.30 a.m:	PR 110, BP 100, urine ok, ketamine 50 mg i.v. Evacuation starts
During evacuation:	Ringer 1000 ml per hour, ketamine 50 mg i.v. every 30 min, flush Macrodex 500 ml and Ringer if BP falls.

Manage pain and fear

Neck and spinal injuries: The pain gives protection against fracture displacement. Do not remove the pain signal.

The acute pain
Effective analgesia improves the respiration and reduces the risk of post-operative complications. Good morphine analgesia from injury, during evacuation, until surgery will also reduce post-operative needs for analgesics. Give analgesics and tranquilizers in repeated small doses i.v. In that way you can better monitor both the effect and side effects in each individual case. If you have no i.v. line in an emergency situation, give the drugs by rectum with a 2 ml syringe (without needle); leave the syringe for 2 minutes to prevent the drugs leaking out. The effect of rectal administration is rapid; use the i.v. doses.

The chronic pain
After dramatic injuries and repeated surgery some trauma patients develop a "chronic pain syndrome". In particular mentally depressed patients are prone to get this complication. The main sign is chronic pain that continues after the injury itself has healed. Suspect a "chronic pain syndrome" is on the way when potent analgesics have no effect or gradually less effect. **Notice:** The chronic pain syndrome does not indicate that the actual patient is a drug addict, that he is "mentally weak" or that he is trying to fool you. His pain is real enough and should be managed seriously. Preventive measures: effective analgesia and mental support all the way during the primary management. Management of the pain syndrome: low-dose antidepressant (amitriptyline); physiotherapy, prevent inactivity; mental support; gradually reduce analgesics; consider nerve blocks, acupuncture.

Use i.v. analgesics
I.m. injections are not effective in circulatory shock patients.

Analgesia must be effective
The correct dose of an analgesic is the dose that gives effective analgesia. There are big individual variations and no fixed standards. The doses listed below are guidelines.

etoclopramide
ntivomiting drug, in combination
th analgesics.
ose: I.v. 0.15 – 0.3 mg/kg (adults:
)-20 mg).
de effects: None serious.

Morphine
The main potent analgesic.
Dose: I.v. 0.1 - 0.15 mg/kg (adults: 5 - 10 mg) in repeated doses.
Side effects: Sedation, monitoring of head injury is diffcult. Respiratory depression by accumulation after repeated high doses. Vomiting, consider metoclopramide to prevent vomiting and reduce the risk of aspiration during evacuations.

Buprenorphine
Synthetic "morphine", potent analgesic.
Dose: I v. 0.3 - 0.6 mg (adults) in repeated doses. Side effects: Same as morphine.

Pentazocine
Non-morphine drug less potent than morphine, but also less side effects. Consider pentazocine where monitoring of the patient is difficult (mass casualties).
Dose: I.v. 0.5 - 1 mg/kg (adults: 30 - 60 mg) in repeated doses.
Side effects: Some respiratory depression and vomiting, but less than the morphine drugs.

Ketamine
Standard drug for wartime anesthesia. In low doses ketamine is a potent analgesic. Consider intermittent i.v. ketamine analgesia during difficult evacuations and in circulatory shock cases.
Dose: I.v. 0.5 mg/kg in repeated doses.
Positive side effect: Pressor effect on the circulation.
Negative side effects: Negative inotropic (p. 149). Mental confusion, hallucinations, unrest. **Routine:** Add diazepam 2.5 - 5 mg i.v. in repeated doses to reduce the mental side effects.

The tranquilizers

What seems to be pain may as much be fear. Many war casualties are mentally exhausted, and confusion is a part of the normal psychological reaction to major injuries. In an emergency setting it is difficult to assess the mental state: Give a small dose of tranquilizers and observe the effect. If the effect of analgesics is poor, test combined doses of analgesics and tranquilizers.

Diazepam
The main tranquilizer. Also anticonvulsive.
Dose: I.v. 2.5 - 5 mg. Anticonvulsive doses may be higher. **Note:** Repeated doses accumulate because of slow excretion; give diazepam less frequently than the analgesics. **Notice:** Great individual variations in effect/dose and duration of action, so monitor closely.
Side effects: Sedation and muscle relaxation may cause airway obstruction. Hypotension due to dilatation of small vessels; so take care in circulatory shock cases.

)o not give drugs to the hypovolemic
:hild that may decrease his PR: His
achycardia is the main protection
gainst circulatory collapse.

Midazolam
Tranquilizer and hypnotic. Compared to diazepam both onset of effect and excretion are more rapid.
Dose – tranquilizer: I.v. 0.035 mg/kg (adults: 2 - 2.5 mg).
Dose – hypnotic: I.v. 0.15 mg/kg (adults: 10 mg).
Notice: Great individual variations in effect/dose and duration of action.
Notice: As the elderly excrete midazolam slowly, reduce the dose by 50%.
Side effects: Depression of breathing, inject slowly (15 seconds). Muscle relaxation may cause airway obstruction. Hypotension, take care in circulatory shock cases.

Chlorpromazine
Antipsychotic, sedative, analgesic and antivomiting drug.
Dose antivomiting: I.v. 10-20 mg.
Dose antipsychotic: I.m. or p.o. 75 - 300 mg/24 hours.
Side effects: Vasodilatation, in particular when combined with analgesics, may complicate circulatory shock. Sedation makes monitoring of head injuries difficult.

Local anesthesia as analgesic

Consider infiltration or bupivacaine nerve block anesthesia before rough evacuations of limb injuries. The duration is better and the side effects less than for drug analgesia. You do well to train your field staff in the most common nerve blocks.

Maximum doses of local anesthetics: p. 668.

- **Fracture analgesia:** If the fracture is not wide open, inject 10-20 ml lidocaine 1% into the fracture hematoma. Femoral nerve block (p. 678) has good effect in femur fractures.
- **Joint injury analgesia:** Unless the joint is wide open, instill lidocaine 1% 10-20 ml into the joint. (Puncture of joints: p. 223).
- **Wrist and hand injuries:** Nerve block anesthesia of the radial, median and ulnar nerves is effective and simple (p. 676). Nerve blocks with plain bupivacaine or lidocaine with adrenaline last four hours.
- **Ankle and foot injuries:** Block the three main nerves above the ankle (p. 679).
- **Chest and high abdominal injuries:** Pleural anesthesia through the chest tube is simple, rapid and gives effective analgesia for 2-4 hours (p. 674). Bilateral extensive intercostal nerve blocks are too elaborate for field use. But consider intercostal block on 3-4 ribs in chest wall or high abdominal wall injuries; also if you already gave analgesics, the nerve block will further improve the breathing.

Early carbohydrate nutrition

Already at the time of injury some war casualties may be hypoglycemic with disturbed metabolism (p. 97). Such cases have less capacity to tolerate injuries

and surgery, and early carbohydrate nutrition should be regarded as part of the BLS procedures. The risk cases are

- Delayed surgery: Major injuries where primary surgery will not be done within 6-8 hours after the injury.
- Late for surgery: Cases arriving after days of evacuation.
- Infected cases.
- Patients starving, undernourished or with chronic diseases.
- Pregnant women and small children: They soon turn hypoglycemic. The younger the child, the higher is the risk of hypoglycemia soon after the injury.

The procedure

- Abdominal injuries and cases with risk of aspiration: Glucose 120 mg/ml, 1000-2000 ml during the evacuation. **Notice:** Glucose is "water", and so the infusion should not be regarded as volume therapy. The rate of infusion should not exceed 250 ml/hour. In weak and starved patients the glucose infusion may cause hyperglycemia, add 40 IU insulin (rapid) to each 1000 ml glucose 120 mg/ml.
- Other cases: Fluid rich in carbohydrate p.o. or through naso-gastric tube.
- Infants: Breast milk or carbohydrate rich fluid by naso-gastric tube. Or glucose 50 mg/ml, 10 ml/kg body weight as slow i.v. infusion.

Nutrients and diets for enteral feeding: p. 616 and 620.

Procedures of basic life-saving surgery

Prevent heat loss – start early warming

The objective: a body-core temperature of 38 degr. C.
At this temperature the clotting factors are active, and the vascular response good.

Protect the body-core temperature:

- Remove wet clothes
- Even in hot climate zones: wrap the patient in blankets and dry clothes
- Room-temperate infusions (30-34 degr. C) cause central cooling: Warm the infusions to approximately 40 degr. C (pack the infusion bag with hot wet clothes, place the infusion tube in hot water bath)

Rewarming before and during surgery:

- Except for the operating field, cover the patient with blankets during surgery
- Warm the infusions and transfusions
- Instill warm water by the bladder catheter
- Instill warm water by rectal tube

Autotransfusions may be life saving

- Autotransfusion is the best alternative: The blood is warm; it contains active platelets, and it is compatible.

Emergency blood transfusions: p. 267.

- Transfusion of warm fresh whole blood is a good alternative: Used within some days after drawing, the blood still contains active platelets.
- Transfusion of old bank blood is a poor alternative. The blood does not contain active platelets. The transfusion helps restore the hemoglobin level and the oxygen-carrying capacity. But it does not solve the main problem: the coagulation failure.
- Transfusion of cold blood promotes central cooling: It is more a hazard than therapy.

Emergency thoracotomy with manual compression or clamping of the aorta

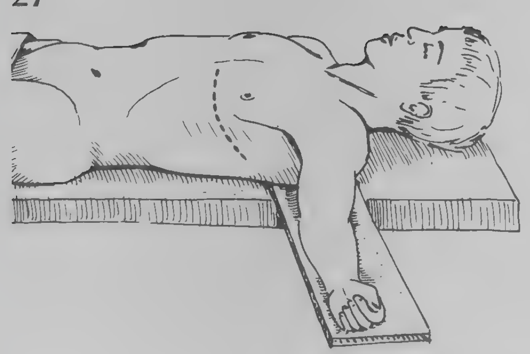
Why

Cases with major vascular injury to the chest, abdomen or pelvis that cannot be controlled by local compression of bleeding vessels: Do not waste time on forward conservative field management. Carry out emergency thoracotomy with temporary clamping of the aorta – or the patient will die. Forward mobile clinics should be prepared to perform emergency thoracotomy. Done early, the procedure is life saving in one out of five cases with missile injuries to the major vessels of the chest and abdomen.

When

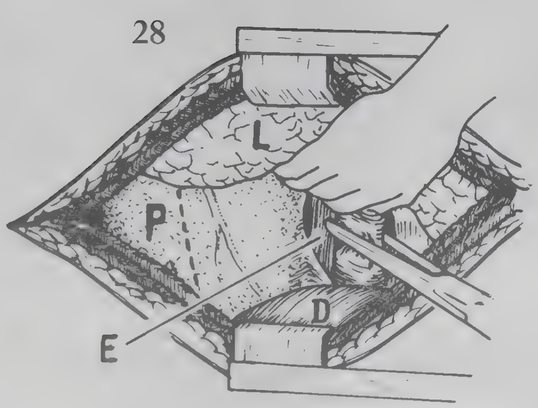
- Abdominal or pelvic injury in patients in grave circulatory shock that does not respond to aggressive volume therapy: Clamping of the descending aorta is done before the abdomen is entered.
- Chest injury in grave circulatory shock that does not respond to aggressive volume therapy: Temporary clamping of major bleeding vessels.
- Penetrating cardiac injury: Definitive surgery is done through the thoracotomy.

27



27 Position on the operating table: Anterior lateral incision for emergencies. Put a few towels under the left side. The thoracotomy may be extended through the sternum into the opposite side. A separate abdominal incision may be done without changing position.

28



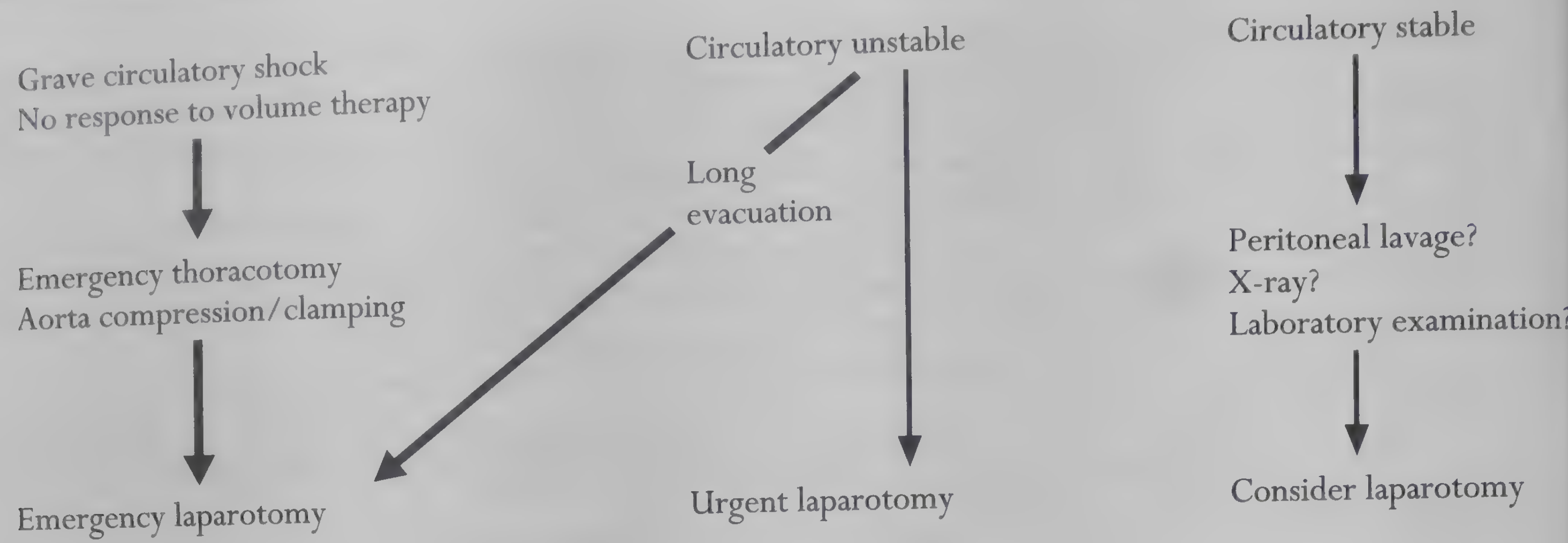
28 Emergency thoracotomy – the procedure: Insert gastric tube for easier identification of the esophagus during surgery. If possible, work with two surgical teams in abdominal cases. Make a left anterior thoracotomy incision from 2 cm lateral to the sternum as far dorsal as possible along the upper edge of the 6th or 7th rib. Apply a Finochietto retractor. Retract the left lung (L) upwards, identify the ligament between the lung and diaphragm (D) – and split it with scissors. You then have access to the pericardium and the aorta. The esophagus (E) is situated in front to the right of aorta: Identify it so as not to damage the phrenic nerve attached to the pericardium or esophagus. The aorta is covered by the parietal pleura – incise it just in front of the vessel.

- **Control abdominal bleeding:** Apply a clamp to the aorta as close to the diaphragm as possible and explore the abdomen. If aorta clamping is needed for more than 30 minutes, open it at intervals to prevent ischemic damage to the spinal cord and abdominal organs.
- **Manual compression of the aorta:** The inexperienced may go directly for the descending aorta without mobilizing the lung. Compress the aorta against the spine with one hand. Compression is tiring and is difficult to maintain for a long time without clamping.
- **Cardiac massage:** The anterior thoracotomy gives good access to the pericardial sac (P). If the patient needs internal heart compression, incise the pericardial sac (dotted line) and perform cardiac massage by compressing the heart against the sternum.
- **Removing the clamp:** Before you remove the aortic clamp, start flushing blood and fluid through all i.v. lines. The clamp has to be removed gradually, releasing the compression stepwise over 5-10 minutes. Manual compression is a good way to gradually decrease the clamping. If you release the clamping rapidly, the blood pressure will fall due to the dilated vessels below the diaphragm, and the patient collapses in hypovolemic shock. Monitor the blood pressure closely during clamp release.
- **Complications to aortic cross clamping:** There is always risk of spinal cord injury after cross clamping. This risk is reduced by applying the clamp as distally as possible on the thoracic aorta. Clamping for more than 30 minutes implies risk of ischemic injury to abdominal organs, failure of kidneys, liver and pancreas may occur after clamping. Intestinal ischemia may cause septicemia, so give broad-spectrum antibiotics for 24-48 hours after the clamping.

Emergency laparotomy

Emergency laparotomy
- is done on dying patients, or on unstable patients before prolonged evacuations
- is life saving
- should be done there and then

Emergency laparotomy
- is done with few and simple surgical instruments
- in the field
- under intermittent i.v. ketamine anesthesia
- by any paramedic trained in the procedure



Preparations for emergency laparotomy

- Establish free airway and effective respiration before the laparotomy is done.
- Control external bleeding from associated injuries.
- Volume therapy: Venous cut-down or central venous catheter to establish two large-caliber i.v. lines. Flush the infusions/transfusions.
- Cases with hemodilution after fluid infusions: Blood transfusion is as important as surgery. Start with O blood; try to get fresh whole blood.
- Instruments: Small general surgical set. Metal cup or a glass for removal of blood. Gauze packs 30x30 cm. There is no time for sterilization or sterile washing.
- Antibiotics: High i.v. dose before and during surgery.
- Anesthesia: Start with i.v. ketamine anesthesia. Consider supplement with general anesthesia when the bleeding is under control. Be prepared for total circulatory collapse when the abdomen is opened.

> **Observe the one-hour limit in unstable cases**
> What cannot be done inside the abdomen by a trained operator within 60 minutes should probably not be attempted at all.

Two different risk factors

The total mortality after abdominal injuries with intestinal perforations is high. There are two main risk factors:

- **Early death due to bleeding:** The intestinal wounds seldom bleed much, but associated bleeding injuries are common. The first priority is to prevent death by bleeding. That is done by a one-hour immediate laparotomy with gauze packing. Then, temporarily close the midline incision. Then re-explore and repair damaged organs by another laparotomy after 24-48 hours.
- **Late death due to peritonitis:** Peritonitis after abdominal injury carries high risk of secondary organ failure and late death. The risk of post-operative peritonitis is a question of proper and early management of the intestinal wounds. But the two objectives – bleeding control, and intestinal repair – may come into conflict: If both the bleeding and the intestinal injury cannot be managed within one hour's surgery, leave the intestinal injury for delayed

repair. The risk of peritonitis in extensive abdominal injuries is high due to poor abdominal blood perfusion.

ethods to control abdominal
eeding: p. 365.

mporary abdominal closure:
379.

Two different types of emergency laparotomies

- **Regarding the first phase mortality:** Control heavy bleeding by aortic compression and gauze packing. The aorta may be compressed or clamped immediately above (better) or below the diaphragm. The intestinal wounds are identified and carefully registered in the Injury Chart/Patient Chart, but intestinal repair is delayed. You may close wounds of the colon with a one-layer continuous suture, or better stop the fecal stream by tying the intestines with gauze bands proximal and distal to the perforations. In the unstable patient there is no time to arrange diversion enterostomies at this stage. Within one hour's surgery the midline incision should be closed. The objective is then to restore abdominal blood perfusion with intensive transfusions as soon as possible – at best restore the hematocrit at 20, and the hemoglobin level at 8 g/100 ml within 1-2 hours after the first laparotomy. Intensive antibiotic therapy is essential.
- **Regarding the second phase mortality:** Divert the fecal stream before a long evacuation. In a stable case with evident intestinal injury (signs of peritonitis, evisceration), diversion enterostomy and naso-gastric tube decompression should be done in the field – if the patient cannot reach a clinic and definitive laparotomy and repair are done within 12 hours after the injury. For diversion enterostomy done in the field, the intestinal perforation/perforations are brought out of the abdominal cavity as stomas. Or a loop-enterostomy is done, using uninjured intestines proximal to the injury (p. 378). The abdominal quadrants with the intestinal perforations are gauze packed. Trained staff can do a field enterostomy through a small midline incision under i.v. ketamine anesthesia within 30 minutes.

Procedures to shorten the laparotomy operation

- Pack tears of abdominal organs with dry gauze.
- Then pack the bleeding quadrants with large, dry gauze packs, 40x40 cm.
- Consider leaving vascular clamps until the second-look laparotomy without tying ligatures.
- Tie the intestines proximal and distal to intestinal wounds with ribbon gauze.
- Consider closing the midline incision with towel clamps.
- Distended abdomen: Suture plastic infusion bags to the abdominal wall fascia to close the midline incision temporarily.

outine exploration of the abdomen:
. 360.

nterostomies in detail: p. 382-386.

Train your forward staff – paramedics and doctors – in the abdominal emergency procedures:

- Gauze packing
- Exploration and tying of the intestines
- Loop-ileostomy
- Transversostomy
- Sigmoidostomy

The procedures are life saving only when done early, that is – in the field.

Liver emergencies

The essentials of the management: Be conservative!
Heroic primary liver surgery with extensive debridements, resections and lobectomies increase the mortality rate even in experienced hands.
- Extensive wound tracks: Like muscle tissue, the tissues of the liver are not elastic and high-energy injuries (penetrating and blunt) may cause extensive wound tracks. The missile shock wave may form hematomas and abscesses at some distance from the wound track. Explore the liver well.
- Spontaneous healing: The liver tissue is very well vascularized. Even major tears heal without debridement. Effective drainage is essential.

The management in detail: p. 391.

Control bleeding – step one

In minor and moderate liver tears the bleeding would normally have stopped spontaneously by the time of surgery. In major and bleeding injuries, first reduce bleeding by the Pringle's maneuver: Control the hepatic artery and the portal vein at the hilum of the liver by finger clamping or vascular clamp (p. 366). You may leave the clamp for 30-60 minutes. Note that the clamping effect may be delayed: The bleeding diminishes slowly due to backward venous bleeding. Permanent ligature of the hepatic artery is safe if the portal vein is not damaged. Tears of the liver veins may cause bleeding from behind the liver: Do Pringle's maneuver and pack under the diaphragm with gauze.

Collect blood for autotransfusion if there are no associated intestinal injuries. The platelets are more important than surgery to control major liver bleeding.

Control bleeding – step two

Then pack the liver wounds with loose gauze swabs or ribbon gauze. Even major bleeding is controlled by mild compression with gauze tampon. Leave the tampon for 24-48 hours without drain.

Control bleeding – step three

At a second-look laparotomy the gauze packs are carefully removed, and drainage arranged.

Injury to the spleen

In multi-organ injuries the management of splenic bleeding is splenectomy – even in minor splenic injuries in children. Splenectomy is the first abdominal procedure to be done when the compression is set on the aorta.

The splenectomy in detail: p. 411.

Duodenal and stomach emergencies

Re-establish the intestinal blood flow as soon as possible
Not only may the patient die from bleeding, the risk of serious complications increases with lengthy hypoxemia of the abdominal organs:
- The intestinal necrosis is extended.
- The risk of rupture of intestinal sutures is increased, particularly so in the duodenum and upper jejunum.

Control bleeding

The stomach wounds seldom bleed much. But vascular damage in the area of the duodenum is common.

- Major intraperitoneal bleeding: If thoracic clamping of the aorta is not done before the laparotomy compress the aorta as close to the diaphragm as possible. Also compress the aorta against the lumbar spine distal to the injury to reduce the back-flow. Remove the blood – identify the bleeding site and examine the duodenum, pancreas, right kidney and the liver hilum roughly.
- Packing, ligature or reconstruction? Suture tears of the aorta, the superior mesenteric artery and the caval vein. Other vascular injuries are managed with ligature if they cannot be safely controlled by gauze packing: ligature of the splenic artery and primary splenectomy. Ligature of the hepatic artery is safe if the portal vein is not damaged. Ligature of one renal artery neccessitates nephrectomy, a time-consuming operation that should be delayed until the second laparotomy. The duodenal arteries are not end-arteries: As there is a rich anastomosing network to the duodenum and pancreas, minor arteries can be safely tied.
- Retroperitoneal bleeding: Do not enter a retroperitoneal hematoma unless it is obviously expanding. Most retroperitoneal hematomas are managed by packing without further surgery. Avoid manipulation of the hematoma during the organ exploration – better delay the routine exploration until the second-look laparotomy when the platelet count and hemoglobin level should have been normalized. If you have to split the peritoneum: First apply proximal and distal clamps to the aorta.

bdominal vascular injury: p. 365.

Drain the duodenum

- You may leave the duodenal injury untreated: Concentrate on naso-gastric suction.
- Intraperitoneal duodenal injury: Before the upper abdomen is packed with gauze, you may insert a tube drain through the duodenal tear into the intestine – a controlled duodenal fistula – if that does not prevent effective packing.
- Retroperitoneal duodenal injury: Do not mobilize the duodenum during on-going bleeding – it is time consuming and will increase the bleeding. Consider inserting a drain through the anterior duodenal wall, but note that you then may enter the hematoma indirectly and spoil the possibility of effective gauze packing.

uodenal drainage: p. 403.

Pancreatic emergencies

Control the bleeding – leave the pancreatic injury

Free leaking of pancreatic juice may complicate other abdominal injuries. Drainage is thus the essential part of the pancreatic injury management – a simple and rapid procedure that should be done if possible also during emergency laparotomies. The pancreatic fistulas that often develop along the drain are seldom a serious complication, most fistulas heal spontaneously.

- Intraperitoneal bleeding: There is no time for extensive pancreatic surgery during an emergency laparotomy. Try to place a large-bore drain at the pancreatic wound. If that is not possible due to gauze packs, better leave the pancreatic injury unmanaged until a second-look laparotomy after 24-48 hours.

The management of pancreatic tears: p. 417.

- Retroperitoneal bleeding: Do not enter a retroperitoneal hematoma unless it is expanding. A possible retroperitoneal pancreatic tear is no indication to mobilize pancreas as that will cause a dramatic and maybe fatal bleeding. Apply drainage and delay the pancreatic exploration until the second-look laparotomy.

Kidney emergencies

The emergency laparotomy is done to save life – there is no time for X-ray urography or other elaborate diagnostic procedures.

- **Insert a bladder catheter:** Hematuria indicates injury to the kidney. No hematuria does not exclude injury to the kidney.
- **Midline incision:** In most cases the source of bleeding is not the kidney injury, but some associated injury. Control the bleeding by aortic compression and/or gauze packing. Leave the kidney without exploration and treatment unless it is bleeding.
- **Heavy bleeding from one kidney:** Pack gauze pads and apply compression towards the bleeding renal compartment. If gauze packing does not control the bleeding: Compress the aorta proximal and distal to the renal arteries (p. 365). Split the peritoneum and control the renal artery and vein (left kidney – p. 423, right kidney – p. 422). Now explore the kidney.
- **Retroperitoneal hematoma:** Monitor the hematoma for some minutes. Hands off unless the hematoma expands rapidly. If you have to explore the hematoma: First control the renal vessels and be prepared for circulatory collapse when you split the peritoneum.
- **Moderate kidney injury:** Pack both the renal wound and the compartment with gauze, leave the drain, and re-explore after 24-48 hours.
- **Extensive kidney injury – experienced surgeon:** Consider primary nephrectomy – resections and suture of the kidney wounds are more bloody and time consuming. In multi-organ injuries, nephrectomy cannot be done within the one-hour limit, and should be delayed until the second-look laparotomy when the patient is circulatory stable. If necessary, tie the renal vessels during the emergency laparotomy, pack the kidney – and remove it after 24 hours.
- **Extensive kidney injury – inexperienced surgeon:** If the renal vessels are not torn, pack the kidney. Re-explore and arrange drainage after 24-72 hours. If the renal vessels are torn, tie them and refer the case for nephrectomy.

The management of renal injuries: p. 425.

Limb emergencies in multi-injury cases

There are two different reasons to do primary amputation on a limb: One – the local injury is so extensive that the limb will not survive. Two – in a multi-injury patient, the limb injury may be a threat to the life of the patient due to other associated severe injuries. In a circulatory unstable multi-injury case, saving the limb may risk the life: Lasting hypoperfusion of the injured limb will expand the area of limb necrosis, which in turn increases the risk of early coagulation failure, osteomyelitis, septicemia and secondary organ failure. So, what we discuss in this context is not limb viability, but patient viability.

ote: The factors are guidelines, not
ules. They should be evaluated in
um, and not separately.

ompare these indicators of **patient
iability** with the indicators of **limb
iability** – see Table 1 on p. 239.

Factors favoring primary amputation in a multi-injury patient:

- There is a severe limb injury with
  - extensive damage of soft tissues,
  - and compound fractures,
  - or injury to one main limb artery.
- The patient has systolic blood pressure less than 90 mm Hg for more than two hours - and does not respond, or responds poorly, to volume therapy. There are injuries other than the limb injury that mainly contribute to the loss of blood or fluid:
  - Chest or abdominal injury with ongoing bleeding not under surgical control
  - Or burns of 40% TBSA or more.
- The patient is more than 30 years old.
- The patient's general condition is poor due to undernourishment, malnutrition, or chronic endemic disease.

Multi-injured burn cases

The extreme loss of fluids in major burn cases makes them vulnerable to associated injuries that bleed, eg. penetrating chest and abdominal injuries, compound fractures. In multi-injury burn cases, circulatory support must include very early surgical control of bleeding. As most fluid is lost during the first twelve hours postburn, the associated bleeding injury should be managed very early, at best within two hours after injury.

One-hour surgery

Surgery done on hypovolemic and hypothermic burn cases carries high risk of circulatory collapse and coagulation failure. Laparotomy and fracture surgery add to the temperature loss. The operation time on associated injuries should therefore be as short as possible: The objective is not definitive repair, but exclusively to manage the main problem at that time. Definitive repair is done if the patient is stable 24-72 hours postburn.

Examples of one-hour basic life-saving surgery in burn cases

- Associated abdominal injury: Make a proximal diversion enterostomy, tie the intestinal wounds to prevent fecal leak, gauze pack the abdomen to control bleeding. Definitive intestinal repair can be delayed 72 hours.
- Associated vascular limb injury: As artery reconstructions are time consuming, tie the vessel. Do secondary amputation if there is ischemic damage.
- Limb crush injury, multiple fractures: There will be an extensive soft tissue injury that adds to the fluid loss and increases the risk of septicemia and secondary organ failure – consider primary amputation.
- Open fractures: Definitive debridement and fracture fixation are time consuming – do fasciotomy, insert double drains, and arrange traction.

Points to note – Chapter 8

Surgery should forward healing, and not be destructive

- know when surgical repair should be delayed, study the two-step method: p. 167
- impose a one-hour limit on laparotomies in unstable abdominal cases: p. 133
- handle the local tissues with care: p. 164

Know the standard exploratory incisions:

- the abdominal midline incision: p. 360
- the upper limb incisions: p. 490, 495, and 504
- the pelvic incisions: p. 473, 474, 477, and 480
- the lower limb incisions: p. 522, 532, and 543

Be familiar with the surgical instruments

- know their use: p. 166-168
- how to clean, maintain, and store instruments: p. 69
- know the details of disinfection and sterilization: p. 656
- how to compose different sets of instruments: p. 58
- instruments for the one-man mobile clinic: p. 66

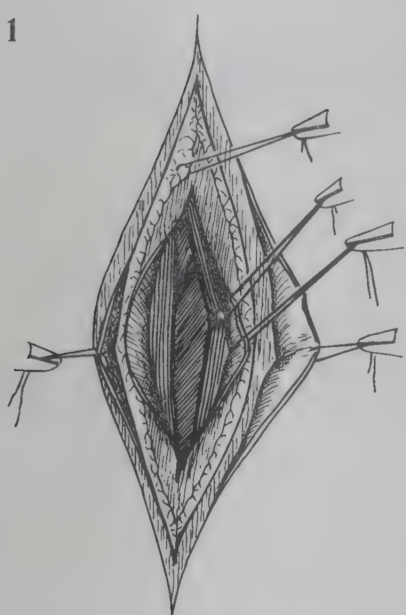
Train in making sutures and knots when you have spare time: p. 169

8 Surgical technique

Non-traumatic technique

Handle the tissues carefully! Your surgery should assist the tissues to heal, not "fight" them. The tissues differ in blood supply, elasticity and capacity for regeneration. Learn to know the characteristics of each kind of tissue.

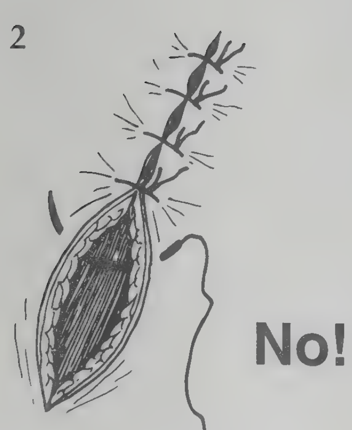
1



1 • **Note the architecture of the tissues:** The tissues are arranged sheet upon sheet – the skin, subcutaneous fat, the main muscular fascia, layers of muscles with thin fascia in between them, and innermost the bone with periosteal lining. Each sheet of tissues has partially independent blood supply. This architecture permits a partly independent movement of each sheet in relation to the sheet above and beneath it. During exploration and dissection, try to move within the space between the sheets, not across them. Also during wound closure, try to re-establish the exact architecture of the tissues to reduce deep scarring and promote limb mobility.

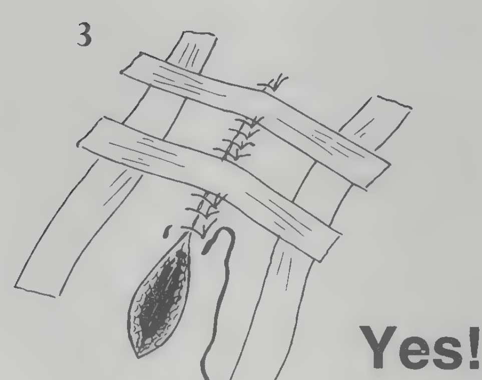
- **Consider the tissue blood supply:** Fatty tissue has poor blood supply; tension and pressure may cause tissue necrosis, and tense subcutaneous sutures are risky. The blood supply to muscle tissue is good. But where muscles are affected by edema and close to a wound track, the blood supply is less: Avoid rough manipulation. Sutures will always strangle some blood vessels and further reduce a poor blood supply. The skin is well vascularized, in particular the skin of the face and male organs. The bone blood supply is carried by the periosteum: Handle it carefully!
- **Consider the age of the patient:** The soft tissue elasticity and vascular supply will decrease with increasing age. The viability after injury of a child's tissues is far greater than that of an old patient. Be conservative in debridements on children; make narrow excisions.
- **Avoid careless tension and pressure on the tissues:** A surgeon "fighting inside a narrow wound" to perform the exploration will damage the soft tissue micro-circulation with his instruments. Deliberate use of wide explorative incisions is less traumatic to the patient.

2



2 • **Avoid tension upon the sutures:** If you cannot close the wound with 3-0 sutures due to tension, do not ask for 1-0. Better leave the wound partly open for spontaneous granulation. Or close it with skin grafts (p. 252). Sutures under tension will obstruct the micro-circulation, cause wound necrosis and infection.

3

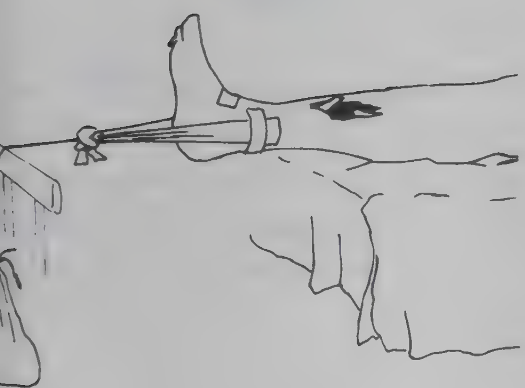


3 **Many interrupted sutures** of fine caliber with short intervals between them produce less tension on each suture than a few sutures of rough material. Cross-taping may further reduce the tension.

s of surgical intruments: p. 58.

intenance of instruments: p. 69.

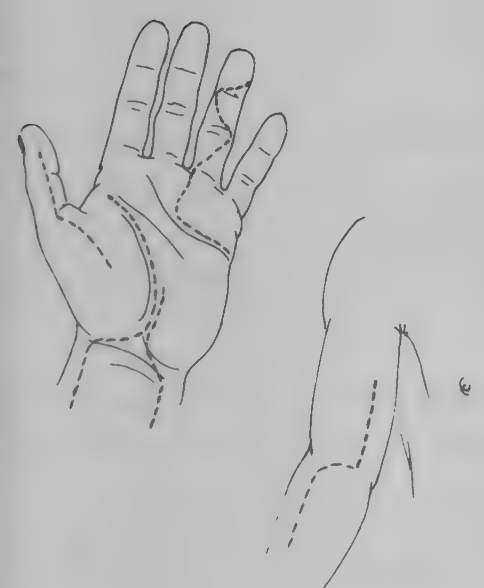
- **Use blunt retractors wherever possible:** The gloved fingers are the "kindest" retractors. They are also the instrument of choice to explore deep wounds. If you pad gauze under the retractors, the retraction is even more non-traumatic and at the same time hemostatic. Never clamp tissues with artery forceps, unless that tissue is to be excised.
- **Surgical scissors and blades must be sharp.** Maintain the instruments well; careless washing and storing will damage them. Blunt scissors and blades will crush the tissues instead of cutting them.
- **Do not let the tissues dry during the operation.** Wet the operation field with NaCl every five minutes. Tendons, nerves and subcutaneous fat will necrose when dry.



4 • **Use temporary traction during fracture surgery:** The traction will ease the bone alignment, and help reconstruct the soft tissue architecture. Manual traction by one assistant or some sort of improvised plaster traction will do.

- **Be restrictive with absorbable sutures (Dexon, Vicryl, catgut etc):** They create some irritation inside the tissues during the period of absorption (within 10-20 days). This is an unnecessary additional trauma to the tissues. In tissues whose viability is at risk better use fine prolene or silk sutures (3-0, 4-0) for the soft tissue approximation.

Choice of incisions



5 • **Use the standard incisions if possible:** To be able to explore all parts of a wound track and make an exact debridement, you have to extend the wound into an exploratory incision. Plan your incisions well. In Chapters 21-39 are listed the standard incisions for exploration of regional injuries. Try to include the wound track into one of the standard incision. Your incisions should not cross the joint flexion lines, but run parallel to them or at least cross them obliquely in a Z-incision. Otherwise the wound may heal with excessive scarring and joint contracture.

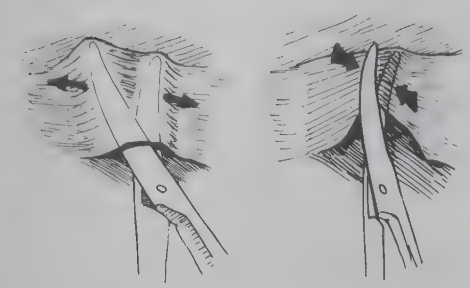
- **Be liberal in your use of additional incisions for exploration.** The second incision may be useful for counter-drainage (p. 181) and to decompress the muscle compartment (p. 177). Improper exploration through one small incision is far more traumatic than adding another exploratory incision.

Dissection and retraction

Careful dissection is the key to trauma surgical handicraft. There are two main methods of dissection. **Sharp dissection:** Cutting your way with knife, scis-

sors, chisels or other sharp instruments. **Blunt dissection:** To open the tissues along the natural spaces between the structures without sharp instruments.

6



6 Sharp dissection with scissors: The scissors must be really sharp in order to cut and not to chew the tissues. First use the scissors to spread open a "tunnel" into the tissues. Then use it as a cutter.

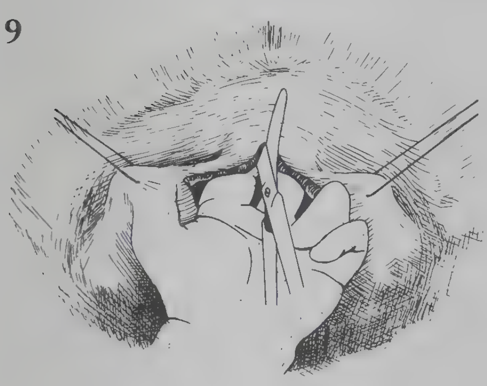
7

7 Dissection with knife: Use the blade and not the bladepoint for cutting. Stretch the actual tissue when cutting it. Here the incision is through the wall of uterus during section. The arrow points to the head of the fetus.

8

8 Blunt dissection should be performed neatly without tearing the tissues. The gloved finger is a good tool, here during laparotomy with mobilization of the rectum from the pelvic cavity.

9



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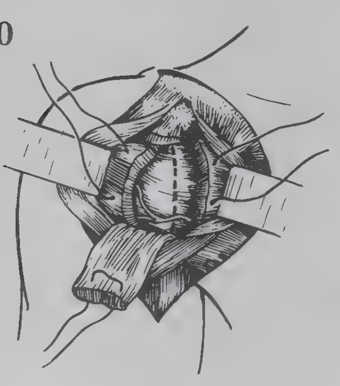


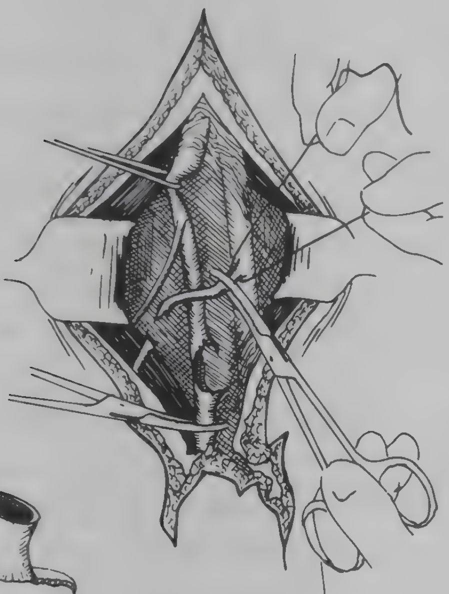
9, 10 Stay sutures for retraction: Stay sutures are eg. inserted before debridement and exploration of a bladder tear. And in exploration of a shoulder joint injury before cutting the muscles.

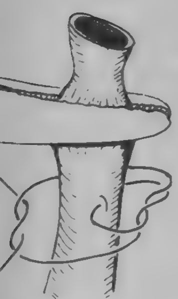
Control of bleeding

The debridement in deep wounds is often insufficient, for two reasons: Poor knowledge of the anatomy and the localization of the main vessels make the surgeon defensive. Also an inappropriate technique for control of bleeding causes too narrow debridements. Some basic and simple techniques make you able to control any bleeding:

Proximal tourniquet – in case: Most bleeding limb injuries are controlled by packing and pressure directly onto the wound. If not, apply the BP-cuff as tourniquet. **Note:** The cuff pressure should exceed 220 mm in order to obstruct the main arteries. When you expect grave bleeding during surgery, better apply the BP-cuff (without inflating it) proximal to the operating field as an "in-case" measure. You may deflate the cuff at intervals during the debridement to identify bleeding points, to evaluate tissue circulation and the extent of necrosis. **Note:** Never use a tourniquet if you suspect there is a vascular injury, increased local vascular pressure may tear a partial injury completely.

One-minute tamponade: At intervals during the surgery, pack gauze into every corner of the wound. Apply firm pressure upon the gauze pack for 1-2 minutes before you proceed with the debridement.

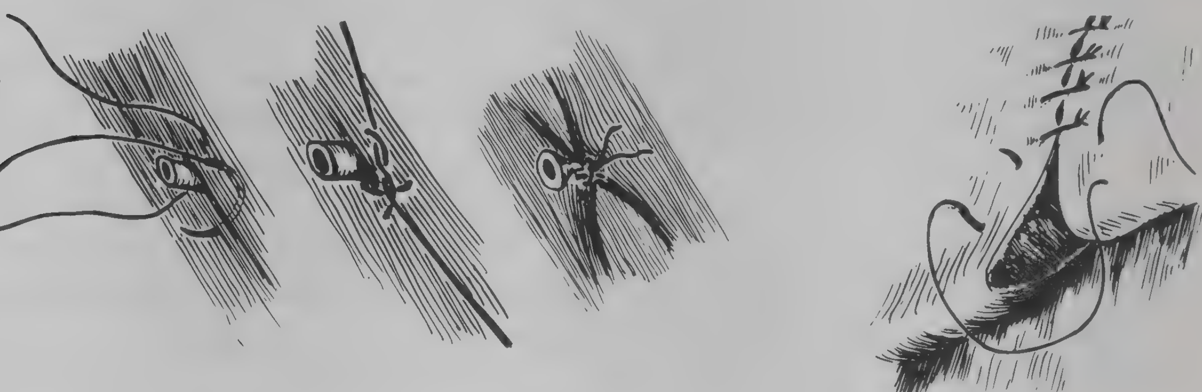




Proximal control of the bleeding vessel – study the anatomy: In Section 4 the main surgical anatomy is listed for each regional injury. Study the localization of the main vessels and the blood supply to main structures and organs. It is too late to consult the manual when the surgery is going on. When you know the anatomy you can extend the incision in the proximal direction and find the main vessel. Or expose the vessel through a small separate incision proximal to the bleeding point. Now control the bleeding by finger clamping or rubber slings on the main vessel.

11 **Permanent control by ligature:** Ligature is the main method for permanent control of any bleeding vessel. Clamp the vessel with the curved side of the artery forceps. Make one knot, and tie it while your assistant releases the forceps **slowly.** Add two or more knots. Use double ligatures on major vessels. If you fear the ligature will slip off the vessel, apply a ligating stitch. The materials used for vessel tie are mersilene or silk (3-0, 4-0) on major vessels. On minor vessels you may use absorbable ligatures (catgut, Dexon, Vicryl).

12



12 **Hemostatic sutures** will control oozing of blood where you are not able to identify one single bleeding source. Bleeding from tears of the inner organs (here: the liver) is also controlled by deep hemostatic sutures. Use a large and well-curved needle.

Temporary tamponade of a deep injury: If you are unable to tie the bleeding vessels, pack the bleeding site with a long gauze band and take the end out through the skin incision. After 24 hours start pulling the band step by step at intervals until it is removed. The method is efficient for retroperitoneal bleeding and for liver or kidney injuries oozing from the debrided area (p. 366).

Two-step surgery in extensive injuries

Reason 1: In abdominal injuries, major limb injuries and multi-injury-cases, bleeding control has priority before the debridement.
Reason 2: There is a one-hour limit for primary surgery in serious and unstable cases. It is our experience that primary surgery lasting beyond one hour in fact increases the risk of complications in extensive injuries.

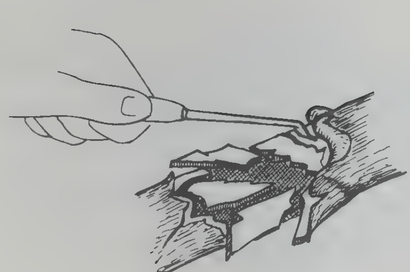
Two-step abdominal surgery in detail: p. 133.

- **Surgery step one – exploration and gauze packing:** Patients in circulatory shock who do not respond to volume therapy are operated on as an emergency. Through wide exploratory incisions the bleeding source is located. If the injury is more extensive than you can manage, if the general condition of the patient is poor and if blood is oozing from "everywhere", pack the bleeding area with multiple big gauze packs and temporarily close the incision with some sutures or circular bandage. If you can reach an expert clinic within 48 hours, refer the case. If not, reoperate the case yourself after 24 hours intensive basic life support.
- **Step two – the definitive surgery:** Now the patient is in a stable condition. But necrotic tissues in the wound track must be excised and intestinal tears closed. Reopen the incision and remove the gauze packs carefully. Identify bleeding vessels and control them by ligature. If bleeding restarts, it is probably more moderate and should be controlled by the techniques illustrated above.

Electro-cautery controls bleeding points and minor vessels. Cautery spares the operation time for the benefit of the patient, and increases the FC capacity. Cautery may also be applied directly to the cutting knife, but only when cutting through tissues where you expect considerable oozing of blood (scalp, lung etc.). On medium and main arteries, cautery cannot control the bleeding – so ligate these vessels. **Notice:** As nerves usually accompany the vessels, do not damage them with the cautery.

Surgery on bone

13

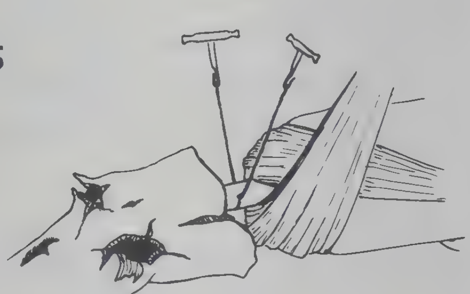


13 Elevate the periosteum carefully. The periosteum carries the blood supply to the bone, it is vital for protection against infection and for bone regeneration. Do not elevate more periosteum than strictly necessary to expose the fracture.

14

14 The nibbler is a bone-cutting instrument. A blunt nibbler is a bone-crushing instrument and should not be used. Eg. enlarge the drill-holes by minor repeated bites by the nibbler during exploration of a skull injury. If you have no bone file, you may also use a sharp nibbler to trim the end of an amputated bone.

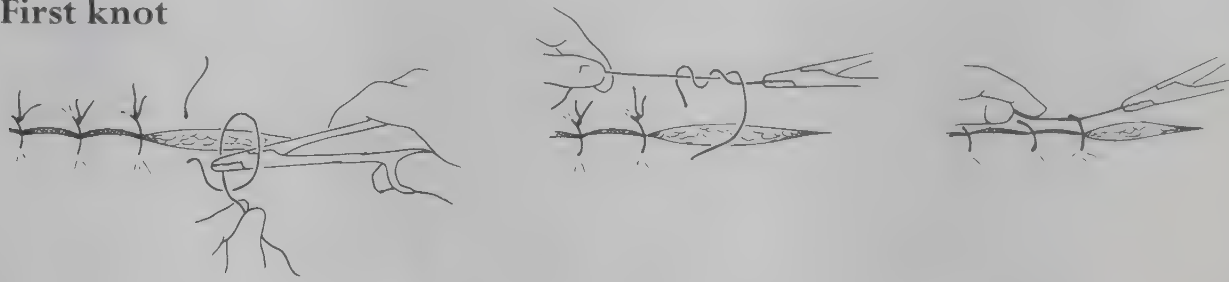
15



15 The saw, be it a straight one or a Gigli saw as illustrated here, may damage the soft tissues. Protect the tissues during sawing. A fine and light **chisel** may also do the job in amputations. Drive it forwards with multiple frequent light blows with the hammer. The chisel must be sharp; a blunt or heavy chisel may fragment the bone.

Sutures and surgical knots

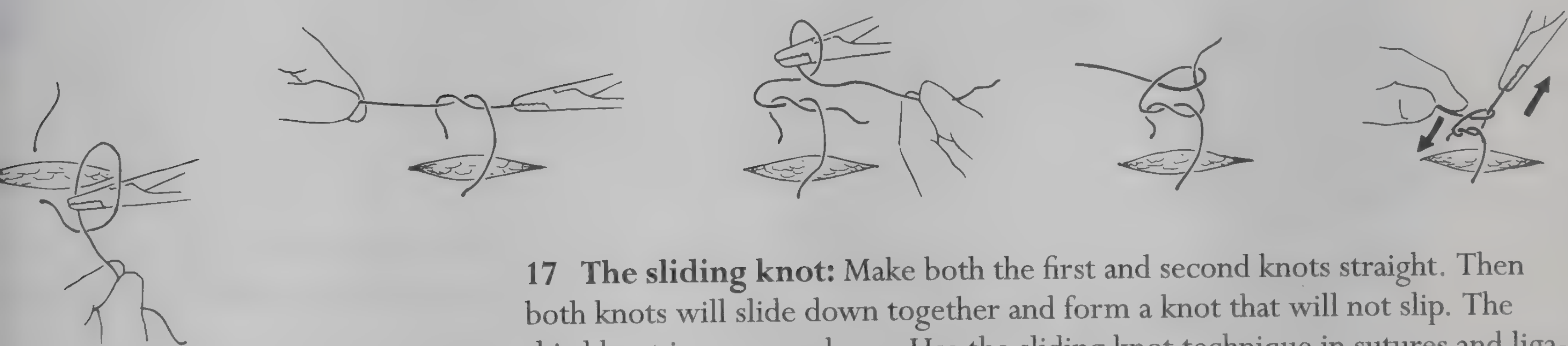
16 First knot



cond knot

Third knot

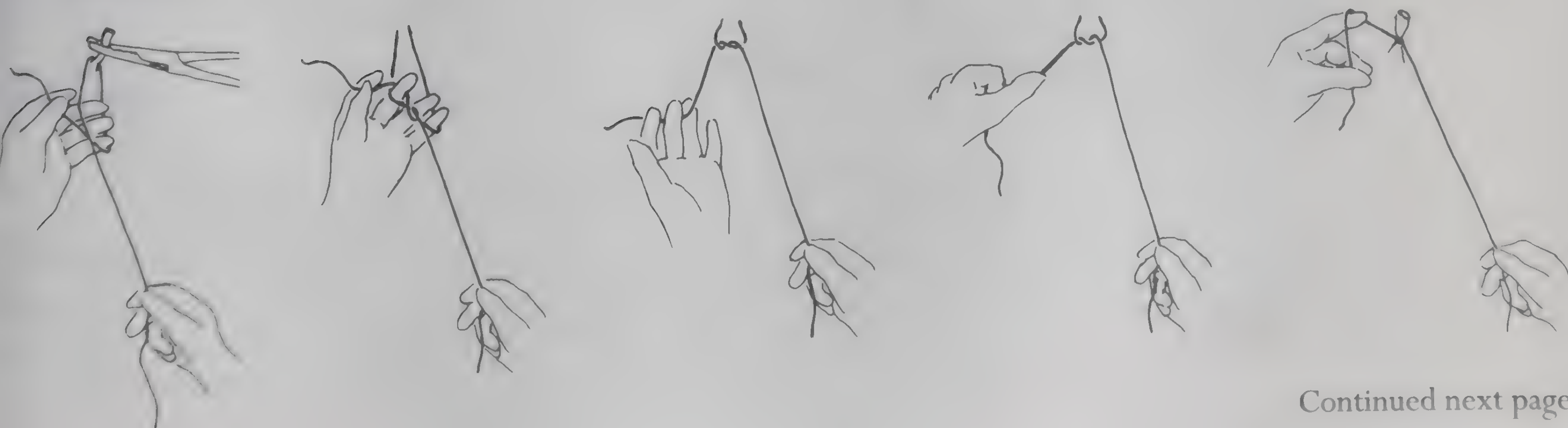
16 The standard surgical knot: In tying the knot, pull the two ends of the suture parallel to the wound in order to locate the knot at one side of the wound, not over the wound line. **Notice:** The first knot is straight and double, the second one reversed and single, the third one is straight and single.



17 The sliding knot: Make both the first and second knots straight. Then both knots will slide down together and form a knot that will not slip. The third knot is a reversed one. Use the sliding knot technique in sutures and ligatures deep inside the wound where access is difficult.

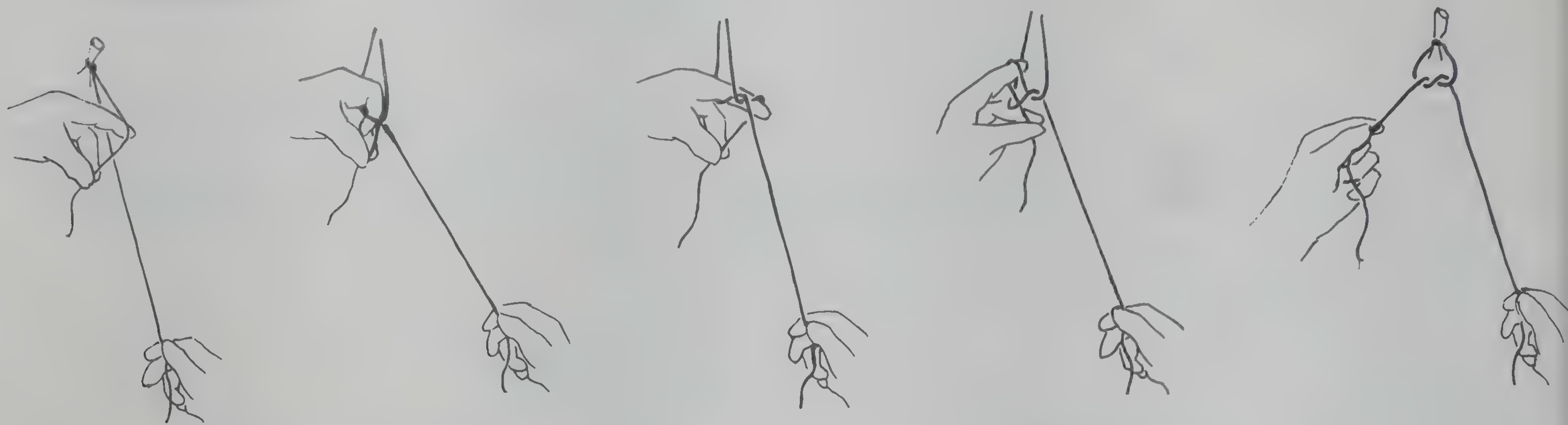
18 The "one-hand-knot": Learn this procedure well. You need it to apply ligatures deep inside the wound. If you are right-handed, your left hand is doing the tying. Keep your right hand steady. Ensure that the long end of the suture is taut all the time.

First knot

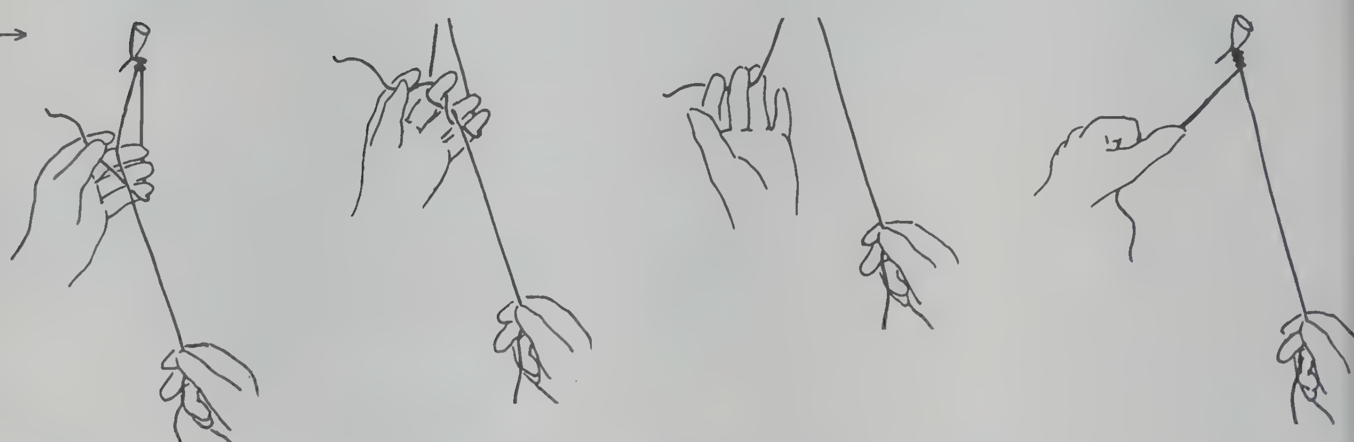


Continued next page

Second knot →



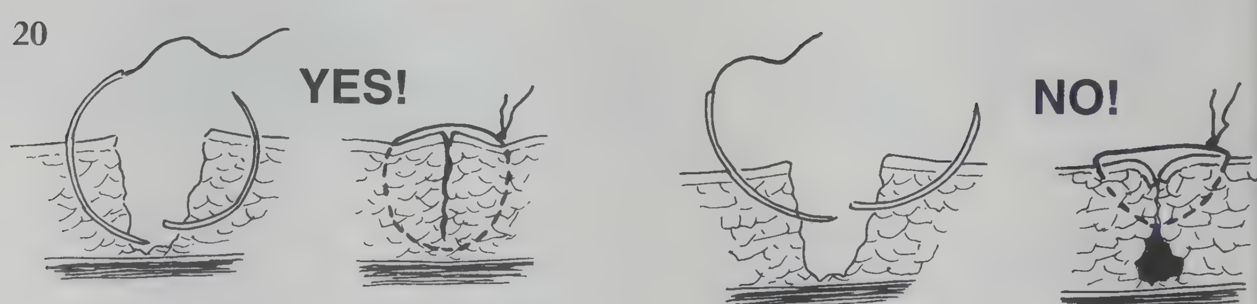
Third knot →



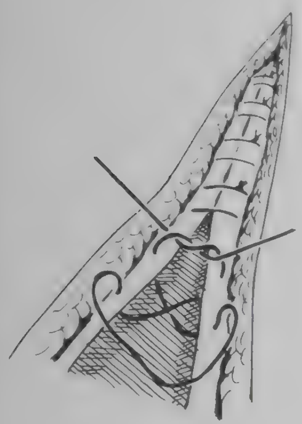
19

19 Suture technique: Grasp the needle between the distal two thirds and the proximal one third. Make it a habit to apply a correct grasp on the needle holder.

20



20 The plain interrupted suture: Drive the needle at a 90-degree angle to the skin surface. If not, the suture will depress the suture line and create a pouch inside the wound where hematomas and infection will collect. **Note:** After the injury and surgical manipulation of the tissues, the tissues will always react with some edema. Take this wound edema into consideration when you tie the suture: The edema will increase the tension on the sutures, and may strangle the blood supply to the wound edges.

1


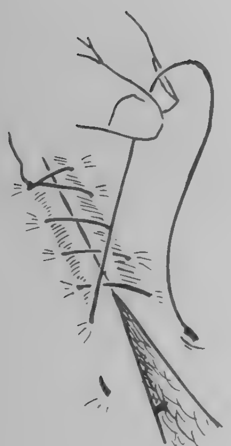
1 **The cross suture** is a steady uture for closure of fascia and joint apsule incisions.

22

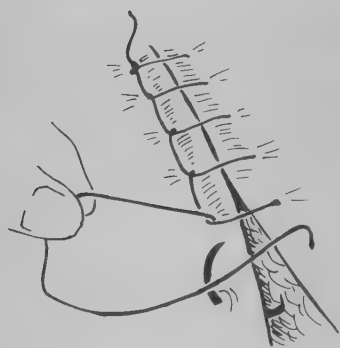

22 **Subcutaneous sutures** should always be interrupted absorbable sutures. Be restrictive with subcutaneous sutures in war wounds. In most cases a deep mattress non-absorbable suture causes less tissue reaction.

23

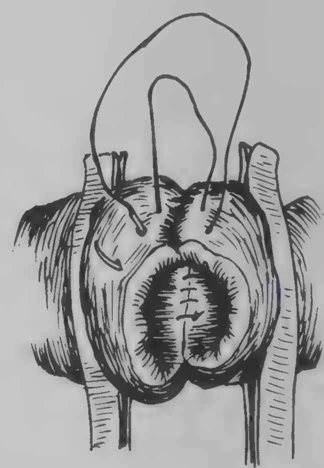

23 **Mattress sutures** close deep wounds. They also evert the skin edges nicely. The superficial part of the mattress suture should just take a tiny bite of the skin.

4


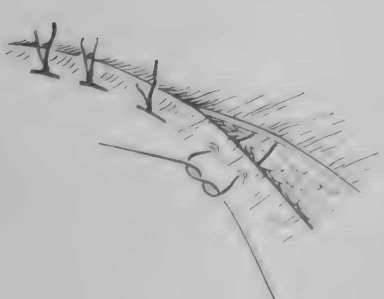
4 **Simple over-and-over contin-ous suture:** Your assistant keeps a teady pull on the preceeding stitch vhile you apply the next one. Close he continuous suture by a standard urgical knot on the last stitch. **Note:** Vhere there is tension on the suture ine, the wound healing is at risk – etter use interrupted sutures.

25


25 **Continuous inter-locking suture** is an alternative to the over-and-over suture. The wound edges are nicely elevated, but the suture obstructs the wound blood supply to some extent.

26


26 **Continuous S-suture** is a standard suture for wounds of the gut. The wound edges are nicely adapted as long as each stitch does not include too much tissue.

7


27 **The Donati suture** is a non-traumatic suture, well fit for cosmetic closure and for fixation of skin grafts. Take care to apply the sutures quite superficially and just to take small bites of the tissues.

28

28 The intracutaneous suture for cosmetic closure of face wounds. The suture runs inside the skin (dermis) all the way. Notice the small step "backwards" between each stitch.

Points to note – Chapter 9

Plan your surgery

- learn how to evaluate open fractures: p. 200 and 514
- learn how to evaluate open joint injuries: p. 218
- know when to repair, and when not to repair artery injuries: p. 187
- know the reasons to do primary amputation: p. 188 and 239
- know the abdominal injuries that have priority in emergency laparotomy: p. 156

The fasciotomy and debridement – also study

- the surgical anatomy and standard incisions in the upper limb: p. 490, 495, and 504
- the surgical anatomy and standard incisions at the pelvis: p. 473, 474, 477, and 480
- the surgical anatomy and standard incisions in the lower limb: p. 522, 532, and 543
- special considerations for mine amputations: p. 85

The drainage – also study

- the abdominal compartments to drain after laparotomy: p. 368 and 392
- the spaces and compartments to drain in the upper limb: p. 486, 493, and 502
- the spaces and compartments to drain in pelvic injuries: p. 432 and 470
- the spaces and compartments to drain in the lower limb: p. 519, 540, and 541

9 Fasciotomy, debridement and drainage

Fasciotomy-debridement-drainage is a three-in-one surgical procedure that is the foundation of wartime surgery. The procedures are technically simple, but the assessment of the tissue viability is difficult, and can only be learnt from experience.

Step one – fasciotomy: to split the muscle fascia by wide longitudinal incisions. The reason is to improve the venous drainage from the wound area, and prevent collapse of the arterial blood supply. Make fasciotomy on all high-energy missile limb injuries as soon as possible, and within eight hours after injury. There are few exceptions to this rule.

Step two – debridement: to remove by surgery all necrotic tissue from a wound. Debride all missile wounds as soon as possible, and within eight hours after the time of injury. There are no exceptions to this rule.

Step three – drain all wounds that penetrate the muscle fascia. There are no exceptions to this rule.

Primary delayed suture: Leave all missile wounds open for at least four days after debridement before wound closure. Except for injuries to the face and the male organs, there are few exceptions to this rule.

Plan your surgery

First: Collect the facts
- What kind of weapon/ammunition/shrapnel caused the injury?
- What was the approximate range of the hit? High-energy or low-energy injury?
- How many hours have passed since the injury?

Second: Perform the clinical examination

The clinical examination in detail: p. 103.

- Remove all clothes and dressings. Wash dirt and debris.
- Look for other injuries.
- From the clinical signs, reconstruct in your mind the probable wound track. Which internal organs and structures may be hit?

Third: Plan your surgery
From the information now collected, prepare each step of the operation jointly with your staff:
- Do you expect much bleeding during surgery? Apply a cuff-tourniquet proximal on the limb. Consider extra i.v. lines. Blood-type and prepare for transfusion. Prepare equipments for autotransfusion.
- Is the case late for surgery? Is it a multi-injury case? Will surgery take more than two hours? Consider antibiotics before and during surgery.

Antibiotic routines: p. 644.

- Is it a high-risk case regarding thrombosis? Consider antithrombotic therapy before and during surgery if there is no associated skull injury or internal cavity bleeding.
- Do you need muscle relaxation during surgery? Decide the method of anesthesia.
- Which incisions do you plan to use? Order the extent of operation field to be washed.
- Decide the position of the patient on the operation table. Arrange padding to prevent pressure damage on nerves, joints or bony prominences during prolonged surgery.
- Is the case already hypothermic? Do you expect prolonged surgery with loss of temperature? Cover the patient with extra clothes during surgery. Arrange a warmer for the infusions and transfusions.
- Fractured limbs: Arrange temporary (plaster) traction before surgery.
- Which instruments do you need, other than the general surgical set?
- Study carefully the actual chapters of Section 4 in this manual, in particular the surgical anatomy.

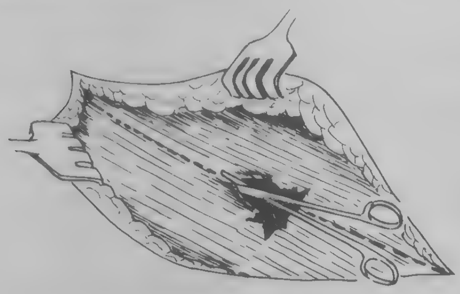
Fasciotomy – when and how

hy fasciotomy – the compartment
ndrome: p. 521.

When to do fasciotomy

- Where there is extensive soft tissue damage: in high-energy missile injuries, comminuted missile fractures, major crush injuries, mine amputations and more than one serious injury in the same limb.
- Where there is/has been poor blood supply: in limb vascular injuries. Also consider fasciotomy in cases with major blood loss and prolonged circulatory shock before surgery.
- Where there is edema and poor venous drainage: swollen and infected limbs late for surgery.
- Do not wait for the signs of impaired circulation: When indicated, the fasciotomy should be done in the battlefield. If definitive surgery is delayed for some reason – do not delay the fasciotomy. Perform the fasciotomy on admission at the clinic under light ketamine anesthesia.
- Patients in circulatory shock: As the risk of circulatory collapse is higher, fasciotomy is even more urgent; do not wait for signs of increased compartment pressure.
- **Urgent:** The limb nerves are very sensitive to hypoxia. General loss of sensory and motor nerve function distal to the injury indicates collapse of the limb blood supply. If neurological signs persist for several hours, fasciotomy is probably useless: It is too late to save that limb.

1



1 How to make the fasciotomy: Extend the skin wound somewhat along the axis of the limb. Insert retractors, spread aside the subcutaneous tissue and identify the fascia wound. With scissors extend the fascia wound under the skin in the proximal and distal direction. Bulging of muscles through the fascia incision confirms the pressure inside that muscle compartment. You were right to do that fasciotomy. Leave the skin incision open over the fasciotomy.

Study the details of compartment anatomy:
- Arm: p. 490
- Forearm: p. 502
- Hand: p. 503
- Thigh: p. 518
- Lower leg: p. 540
- Foot: p. 541

Notice: Make long fasciotomies, as short fasciotomies do not decompress sufficiently. In order to work, a fasciotomy should at least be two thirds of the joint-to-joint or compartment length. **Notice:** There are several separate compartments of muscles on each section of the limbs, and all main compartments must be opened.

The debridement in detail

The disinfection

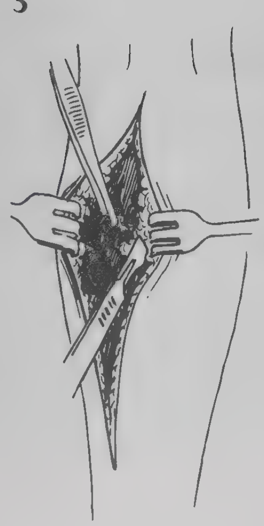
The missile wound is always contaminated as patients are admitted from the combat area with dirty clothes, dirty dressings and dirty wounds. In emergencies: Take the patient directly to the operating room. Ignore the dirt.
In non-emergencies:

- Remove dirty clothes before taking the patient to the operating room. But leave on clothes and foreign bodies stuck or burnt in the wounds. They should be removed only during surgery.
- Instill dilute soap solution into the wounds (50 ml syringes) on admission. Leave it for 10 minutes or more, then rinse with abundant boiled water or NS.
- Wash the operation field with soap solution. In all disinfection, time is the important factor, not the kind of antiseptic solution you use. Wash a wide operating field for 10 minutes.

Disinfectants: p. 657.

2

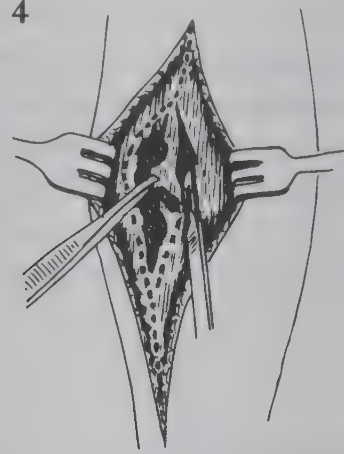
3



2 Debridement of the skin: The skin is elastic and resists the shock wave well. Excision of the skin edges should be limited, in most cases 5 mm is enough. In the face and neck the skin blood supply is rich, and the excision even more limited.

3 The longitudinal exploratory incision: Extend the skin wound in the proximal and distal direction to form an exploratory incision. In Section 4 the standard regional incisions are illustrated. Take care if incisions run across a joint: p. 165. As the blood supply to the subcutaneous tissues is poor, the debridement of fat should be more extensive. Necrotic fat tissue is not shiny, but dull. It has no bleeding points when you cut it.

4



4 Debridement of the muscle fascia – and fasciotomy: Only ragged edges of the fascia should be excised. Then make a fasciotomy: Extend the fascia wound along the fibers proximally and distally to explore the muscles. If this is a high-energy injury, and if the underlying muscle is swollen and tense, extend the fascia incision proximally and distally to make a regular fasciotomy.

5

6

5 Debridement of the muscle tissue

Evaluation of muscle viability is difficult, even for the experienced surgeon. Consider the main points:

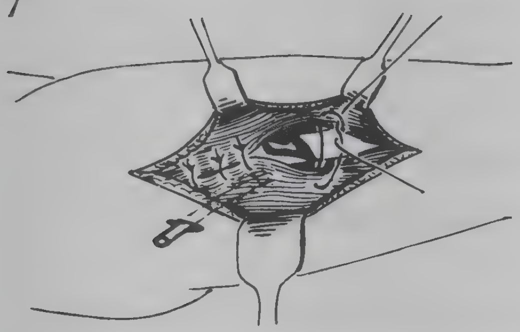
- **The age of the patient:** Make limited debridement in children, more extensive ones in the elderly.
- **More than eight hours' delay before surgery:** The debridement should be more extensive.
- **Blood loss and circulatory shock before surgery:** Extend the debridement.
- **High-energy injury:** The debridement is generally more extensive than in low-energy injuries.
- **Explore in the distal direction:** In general the muscle blood supply is poor distal to the injury. Most often the debridement should be more extensive on the distal side of the wound track.
- **Islands of necrotic tissue:** At some distance from the wound track you may find small isolated areas of necrosis in muscle bellies otherwise undamaged. In particular explore close to the long bones in open comminuted fractures.
- **Belly necrosis or compartment necrosis:** The shock wave may travel mainly along one muscular belly or inside one muscle compartment – and leave the neighboring muscles without damage. And you may find one muscle compartment necrotic, while the neighboring compartment is undamaged. In particular compartment necrosis occurs in the lateral lower leg compartment (p. 540).

6 • **Fragmentation of bone indicates necrosis:** Most open fracture infections arise from necrotic pockets close to comminuted fractures.

- **Assess the local muscle tissue – but do not trust the "four C's":** Capillary bleeding, contractility, color and consistency are said to be the four indicators of viable muscle tissue. It is not that simple: (1) Viable muscle has multiple bleeding points when you cut it; necrotic muscle does not bleed from the capillaries. This is a safe and early sign of non-viable tissue. (2) Necrotic muscle is flaccid, while viable muscle may contract when you pinch it with the forceps. But an edematous

and viable muscle may contract poorly or not contract at all. (3) Necrotic muscle is said to be dark, viable muscle red. But a cyanotic muscle is also dark – even if it is not necrotic. (4) The muscle consistency is also unreliable as an early indicator: Local edema can make necrotic muscle tense soon after injury. In cases late for surgery and in infected wounds the necrosis may be soft.

7



7 The debridement of fractures: The healing of any fracture depends mainly on skilful soft tissue surgery and not on the debridement of bone itself. The main points are the following:

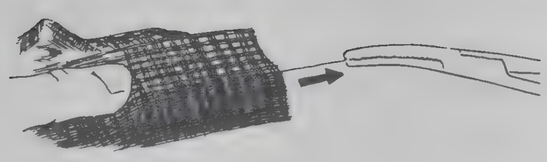
- Periosteum is the key to bone regeneration. Debride it carefully; only necrotic tags should be excised.
- Minor bone fragments without soft tissue attachment should be removed. Major loose bone fragments may be removed, washed with soap and NS, and replaced in the fracture as a bone graft – on one condition: that you cover the fracture with viable soft tissue when the debridement is finished. Otherwise, that bone graft will not take.
- Bone fragments attached to the periosteum should be realigned.
- With a few interrupted sutures adapt viable muscle loosely to cover the fracture.
- Do not compromise on the muscle debridement in extensive injuries. If you cannot cover the fracture when the debridement is done, either prepare a muscle flap or consider if this is a case for primary amputation.

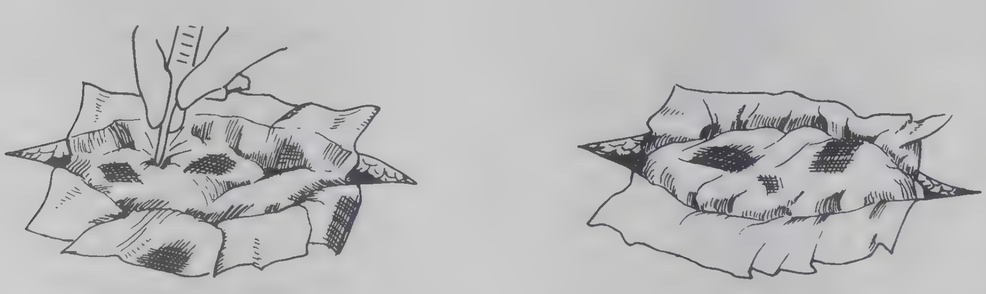
Muscle rotation flaps: p. 200.

Methods for drainage

Efficient drainage is as important as the debridement itself. Retention of blood and tissue fluid inside the wound may cause infection. Not only should each deep pocket inside the wound track be drained, but also the layers and spaces between the muscles: You must know the local anatomy. Thus, drainage of a major war wound is a task for the surgeon who did the debridement; it should not be left to an unskilled assistant.

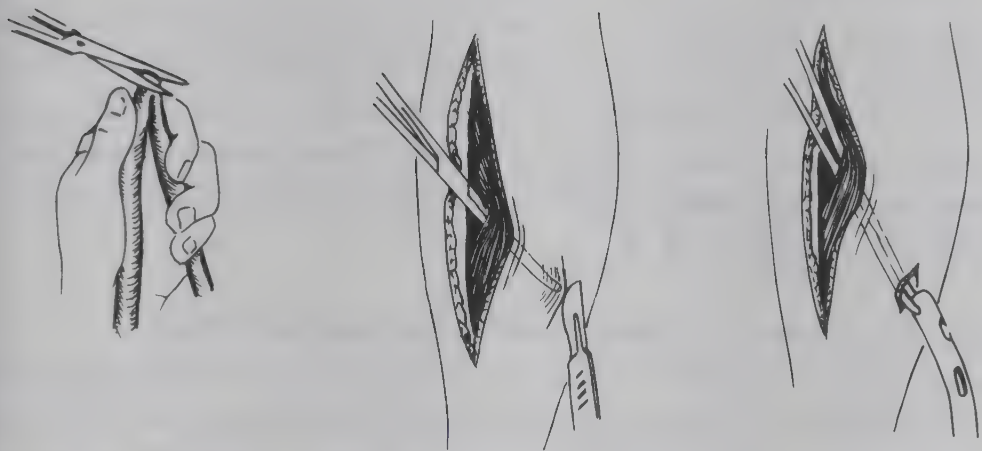
8



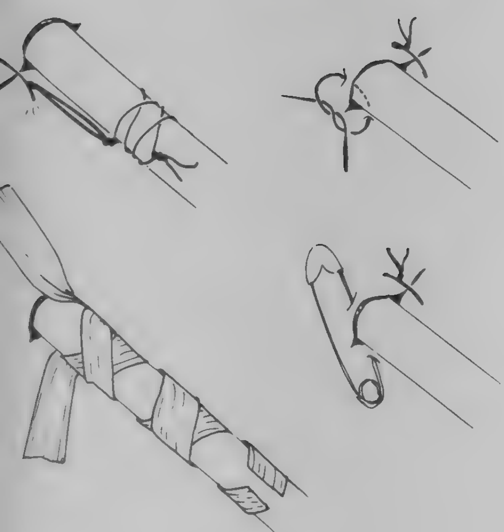


8 Gauze drainage: The gauze has good suction capacity as long as it is loosely packed into the wound. It should be soft, clean and fine meshed. If it is tightly woven, pull some threads from it. A sheet of gauze is placed over the wound and put carefully into all deep pockets. The wound is thereafter filled up to

surface level with loosely packed gauze before a circular dressing or plaster cast is applied. Do not worry about the gauze drain being difficult to remove. A major dressing 3-5 days after the debridement should be performed under some kind of anesthesia anyway. During repeated dressing you may soak the wound with soap solution to release the gauze drains.



9 Dependent tube drainage: Fluid will run through the tube by the force of gravity, and the pressure of the fluid collecting inside the wound. You may use any soft tube, but not so soft that the tube becomes obstructed by bends. With a diameter at least 8 mm the tube will not clot. Cut some side holes in the tube. Make a separate incision for the tube and "railroad" it through that incision. Put the tube ends into the deepest and most proximal pockets of the wound.

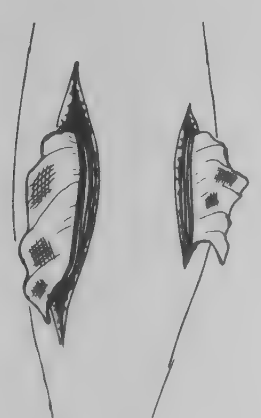


10 Secure the tube drain: Either close the drain incision around the tube with a suture, and tie the tube with that same suture. Or fix the tube with a suture or a needle through the tube wall. Or secure it with adhesive tape.

Warning: Suction drains are not efficient in major war wounds. The caliber of the suction tube is small and the tube will clot. Even if it does not clot, dependent drainage has proved more efficient. And suction drain systems are definitely more expensive than water tubes bought in the local hardware store.

e Trueta plaster cast in fracture
anagement: p. 208.

11



11 Counter-drainage: In deep wounds one drain is not sufficient. A counter-incision will ease the debridement of the deep parts of the wound track – and also improve the drainage.

12

12 The method of Trueta – the plaster cast as suction drainage: The method is named after the English war surgeon Joseph Trueta who joined the Republican side during the Spanish civil war 1937-39. He developed this simple and very efficient drainage system. In addition to drainage, the Trueta method provides fracture fixation, pain relief and makes the patient fit for further evacuation. We recommend the method for major soft tissue injuries as well as open fractures. The wound is filled up to the surface with gauze drain (ill. 8). Except for small cotton pads over the bony prominences, the plaster is wrapped directly on the skin without padding. The limb is elevated. After some days the cast becomes increasingly colored as the plaster continuously sucks the fluid through the gauze drain by capillary action. **There is one condition for the Trueta method to work:** The debridement must be complete and the gauze drainage very exact.

In emergencies: Leave the debridement, but not the drain!
You may be in a hurry or under military pressure, and are not able to perform a proper debridement. When there is reasonable blood supply, the body is able to discharge much necrotic tissue from a wound track – provided you arrange the drainage: Extend the skin and fascia wound. In major injuries also perform fasciotomy of the superficial compartment. Instill soap solution into the wound track with a 50 ml syringe, and insert a gauze or large tube drain. You should be able to complete the whole procedure within 10 minutes.

Section 3
General procedures

Points to note – Chapter 10

External bleeding is not a common sign of artery injury

- repeated, exact clinical examinations are necessary. Recognize the clinical signs of artery injury: p. 114
- intimal injuries are common: p. 186. Study how intima detachment happens: p. 82

Know when artery repair should not be done

- evaluate the total limb injury: p. 187 and 514
- be conservative in crushed limb injuries: p. 187 and 527
- note which arteries may be safely ligated: p. 188
- know how to control abdominal vascular injuries : p. 365

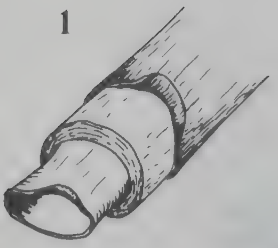
Thrombosis after injury and surgery is common

- note the clinical signs of artery thrombosis: p. 593
- note the clinical signs of venous thrombosis: p. 593
- certain factors increase the risk of thrombosis: p. 239
- know the antithrombotic therapy: p. 594

10 Injuries to arteries and veins

Types of vascular injury

1



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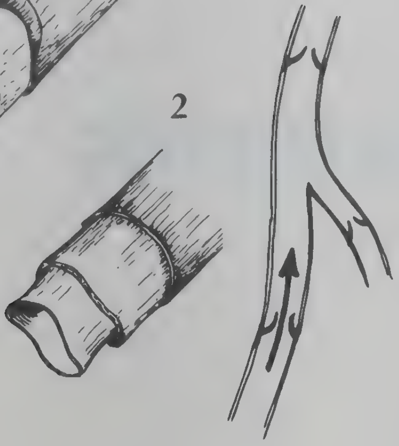
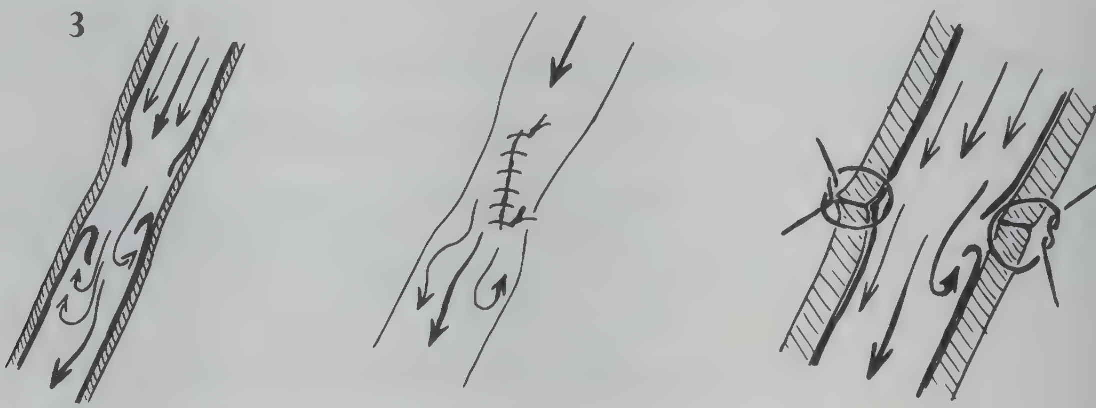


1 The anatomy of an artery: The inside is lined with a smooth thin layer - the intima. Outside the intima is the media, consisting of muscular and elast tissue. The outside is lined by a sheet of loose connective tissue – the adventi

2 The anatomy of a vein: The intima lines the lumen. The venous media i thin compared to that of the artery. **Note:** The vein is equipped with valves a intervals. The valves represent no obstacle to the central flowing of blood, b prevent reverse blood flow.

3



3 Blood clot formation complicates vascular surgery: The blood contains a sophisticated chemical system that forms a blood thrombus (blood clo This clotting system is activated by several chemical and physical factors (p. 593). Regarding injury and surgery, the following factors increase the risk of thrombus formation:

- Prolapse of the intima due to the injury.
- Unsuccessful artery repair with narrowing of the artery and turbulence dist to the narrowing.
- Unsuccessful repair with ragged adventitia causing turbulence and clot form tion in the lumen.
- Infection and hematoma at the site of artery repair.

Three main types of vascular injury

4

- **The closed vascular injury** is the most common wartime vascular injury. It may either be a tear and detachment of intima which gradually blocks the vessel. Or a hematoma inside the wall of the vessel. In both cases secondary thrombosis will gradually obstruct the vessel **(4).** The mechanism of injury i either a pressure wave from a mine blast or penetrating missile. Or tension due to displaced fracture fragments. Or crushing of the vessel in a blunt trauma. At the surgical exploration the signs of the injury are modest: There may be no local hematoma. The artery is continuous with one segment that may be somewhat thinner and darker indicating an intimal roll-off. Only an exploratory incision into the artery can confirm the diagnosis. The repair consists of debridement and suture of the intima. **Warning:** Do not accept the diagnosis "vascular spasm" in an injury case. Inside most "spasms" you will find an intimal injury.

5

- **The open vascular injury** may be one with a side hole, parietal tear or total rupture **(5)**. It is caused by direct hit of a penetrating projectile or bone fragments acting as secondary missiles. In most cases there is a major hematoma. Even if the condition is stable at the time of surgery, heavy rebleeding will start when you enter the hematoma: Always control the vessel before you explore the site of injury (p. 189).

- **The crushed limb complex:** After a heavy blunt trauma (entrapment in bombed houses, crushing by vehicles), the patient may present you with a complex picture of massive vascular injury: crush injury of small, medium and major vessels; collapse of the micro-circulation due to local hematoma and compartment syndrome; extensive secondary thrombosis. As the management is difficult, we advice a two-step approach: **Step one – operation time maximum one hour:** Start infusion of Dextran 70 and perform wide fasciotomies of all compartments immediately on admission. Excise obviously necrotic soft tissue, but do not make an elaborate deep exploration. Drain well, elevate the limb – and monitor the distal circulation closely. If the distal circulation improves, concentrate on prevention of thrombosis and infection. If the circulation does not improve within eight hours, proceed to step two. **Step two:** Make an exact debridement of the subcutaneous fat and non-viable muscle. Explore the main vessels. Consider reconstruction if the vascular injury is limited to one or few segments (vein graft, interposed or as by-pass). The condition for successful reconstruction is enough viable soft tissue to cover the anastomosis. Consider primary amputation if the loss of soft tissue is extensive, if there are wide obstructed segments on several levels, or if the patient is old.

hrombotic therapy: p. 594
ıylactic antibiotics: p. 644

Primary amputation, ligature or reconstruction?

Evaluate the patient – not only the vascular injury

- The multiple-injury case: Do not spend hours on reconstruction of a limb artery if the life of the patient is at risk due to more serious injuries. Consider primary amputation or ligature of the artery.
- How old is the patient? In general, children and young patients are less prone to develop thrombosis and secondary infection. Also their limbs may survive due to better collateral circulation after injuries and complications where the old patient's limb would be lost.
- A six-hour limit? Cases late for surgery, in particular cases with an episode of circulatory shock, carry a high risk of secondary amputation after reconstructions. The risk of complications increases rapidly if more than six hours have elapsed since the injury.
- The nerve function distal to the injury has been lost for 6-8 hours: The results of vascular reconstruction are very poor. Consider primary amputation.
- There is extensive nerve damage and fracture in addition to the vascular in-

jury: The best possible result will be a painful "cosmetic" limb. Consider pri mary amputation.

- There is considerable loss of soft tissue; the artery has no soft tissue cover when the debridement is done: The reconstruction will probably be complicated by infection, thrombus formation or secondary rupture of the artery with sudden heavy bleeding. Consider primary amputation.
- Avoid vascular reconstructions in an infected field. It may be primary infection in cases late for surgery. Or secondary infection after the vascular repair is done (p. 194).
- There are mass casualties arriving at your clinic, many of them serious. Vascular reconstructions are time consuming, and other patients may die while you try to save one limb. Consider ligature or primary amputation.

What do you risk by ligature?

The vascular reconstruction itself is not technically difficult. Most important is meticulous and careful handicraft. Consider your own skills as a surgeon, and start doing reconstructions when they are well indicated. But notice: Even in the hands of a skilled vascular surgeon, wartime vascular reconstructions carry a high risk of complications. Thus reconstructions should not be a matter of prestige; in many cases bleeding control by ligature is no "inferior" way of management.

Table 1
The risk (in %) for secondary gangrene and amputation after permanent ligature (young patient without associated injury)

Other factors also influence the risk of secondary gangrene: see p. 239.

Axillary artery	25
Brachial artery (proximal to the deep artery)	50
Brachial artery (distal to the deep artery)	25
Radial artery	2
Ulnar artery	1
Common iliac artery	75
External iliac artery	30
Common femoral artery	50
Superficial femoral artery	30
Popliteal artery	60
Anterior tibial artery	5
Posterior tibial artery	5

Primary amputation: The decision may be difficult to take. The risk of complications is low, the period of hospitalization short and the load upon clinic minimal.

Artery ligature: In the brachial, femoral and popliteal arteries the risk of secondary amputation is considerable. With close monitoring and secondary amputation in due course, the risk of complications is low. The period of hospitalization is short.

> **Unsuccessful vascular reconstruction:** Repeated operations increase the risk of serious complications. The period of hospitalization is increased 3-4 times, and the load upon the clinic is high.

Exploration

Preparations to surgery

uments for vascular surgery:
9.

X-ray arteriography has limited place in primary management of wartime vascular injuries. It is time consuming and the injuries must anyhow be explored and debrided. Give prophylactic antibiotic and antithrombotic therapy during and after vascular reconstructions. **The antithrombotic therapy:**

- Dextran 70 infusions, 500 ml per day. Start before or during the surgery, continue for two days.
- Consider subcutaneous injections of heparin 5000 IU every eight hours for one week. **Notice:** Do not give heparin to head injuries and cases with internal cavity bleeding or hematoma formation.

6

6 **The operation field:** Wash a wide field, since during surgery you want to check the pulse volume proximal and distal to the injury. As a routine, wash the opposite lower leg in case you need a venous graft from the great saphenous vein. If both legs are injured, a vein graft may be taken from the lateral arm vein.

Veins are reconstructed in the same way as arteries. Sufficient venous drainage is particularly important during the first three days after injury. If both the artery and vein are damaged, first reconstruct the vein. The lateral arm vein (brachiocephalic) and the femoral vein should always be reconstructed and therefore explored – even if there are no signs of artery injury.

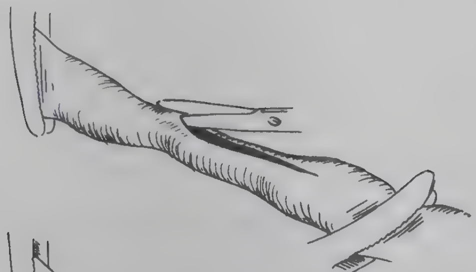
Step one: Control the vessels through a separate incision

We advice you to control and explore the vascular injury before you debride the wound track. If there is a hematoma at the site of injury, you risk heavy bleeding if you enter the hematoma directly. Also it is important to cover the vessels with viable soft tissue when the reconstruction is done. Do not use the wound track for the exploration and vascular reconstruction. Make a separate standard exploratory incision 5 cm to the side of the artery to secure a soft tissue flap for closure. Extend the skin incision proximal and distal to the hematoma, but leave the fasciotomy until step two. Identify the artery and vein well outside the wound track by careful dissection. Apply vascular clamps or double slings of silicone or rubber on the vessels. If the damaged area and hematoma are wide (crush injuries), isolate and control the vessels through separate small incisions well outside the damaged area. **Notice:** Do not use ordinary hemostatic forceps on the main vessels. They cause permanent damage to the vascular wall.

Step two: Explore the site of injury

Now make a wide fasciotomy, insert retractors, evacuate the hematoma and wash the field with normal saline. In a total tear, the torn ends of the vessel retract into the soft tissues and may be difficult to identify. Release the proximal and distal control at intervals and identify the bleeding site. Note that an artery also bleeds from the distal direction. Take care not to damage or ligate collateral vessels during the dissection. Explore the vessels very carefully: A minor side-hole injury may be difficult to identify. Even if it caused an extensive hematoma, the bleeding may have stopped at the time of surgery due to thrombosis at the site of injury. If you cannot find signs of injury despite evident clinical signs, clamp the lumen proximal and distal, inject normal saline into the lumen (fine-caliber needle) to inflate the vessel. Look for leaking and narrow or wide segments. If the diagnosis is still unclear, make an arteriotomy

7



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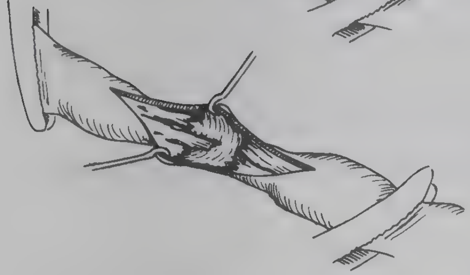
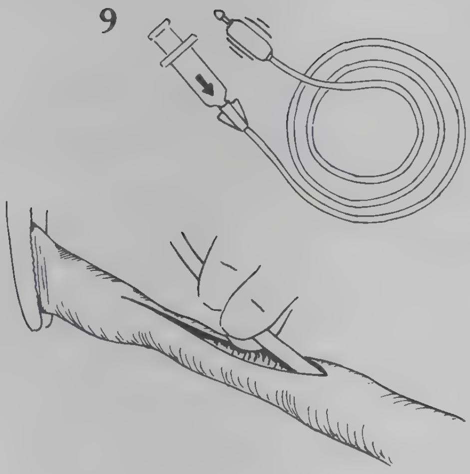


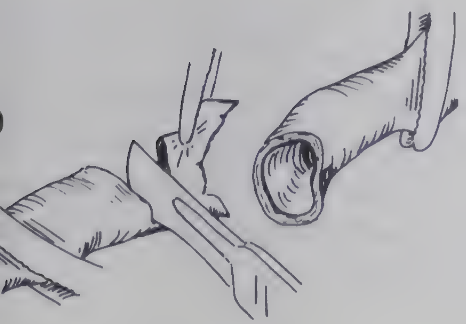
7, 8 Incise the artery – arteriotomy
The artery is incised with a pointed knife, and further split with small (vascular) scissors. Hook the incision with dura hooks or stay sutures. Wash away blood clots and assess the injury. In this case there is an intimal injury with prolapse of intima into the distal lumen.

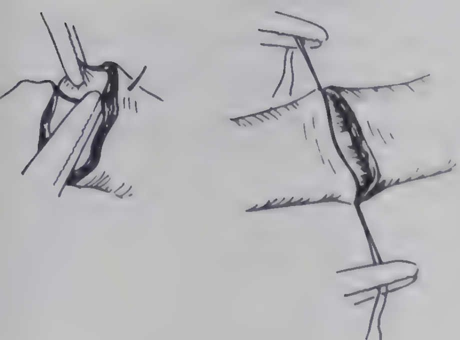
9



9 Remove blood clots – embolectomy
The embolectomy catheters are of different sizes depending upon the caliber of the actual vessel. The soft balloon at the end of the catheter is inflated with water from the syringe. Drive the embolectomy catheter carefully in the distal direction. Start to withdraw it before you inflate the balloon. Inflate the balloo only to that point where you feel it makes a slight resistance to the traction. Now withdraw the catheter slowly pulling blood clots out through the arteriotomy. Repeat the procedure until there is free back-flow of blood. Then instil a dilute heparin-saline solution (20 ml heparin-normal saline, 100 IU/ml) into the lumen before you apply the distal clamp. The same procedure is repeated i the proximal direction while you clamp the distal run to prevent the thrombus from entering. **Notice:** Do not force the catheter when you introduce it. Resistance indicates an intimal injury. Explore it!

> Now reassess the situation and decide whether to proceed with vascular reconstruction or to do a primary amputation:
> - The vital signs of the patient and associated injuries: Can he tolerate prolonged surgery? Consider the general risk of complications.
> - Is there good back-flow from the artery? If not, there may be one distal injury that you did not recognize. Or there is already extensive thrombus formation that occludes the micro-circulation distal to the injury. In any case there is a high risk of unsuccessful repair.
> - Is there good flow from the artery? If not, you risk thrombotic complications after the repair.
> - Can the anastomosis be covered with vital soft tissues? If not, infection and thrombosis will develop.

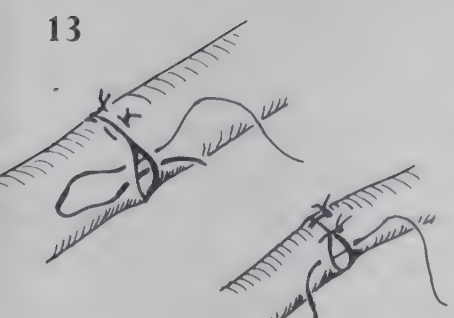




ged soft tissues: Consider
g a new canal for the artery
e the anastomosis is done.

e materials:	Prolene (or silk).
:	3-0
rteries:	4-0
ral artery:	5-0
l arteries:	6-0

13



Reconstruction

10 Debride the artery: An intimal tear may be sutured directly with single stitches through all layers of the vessel, tied on the outside (ill 12 below). If there is crushing of the vascular wall debridement is necessary: With knife or sharp scissors excise maximum 0.5 cm of viable artery proximal and distal to the injury.

11 End-to-end anastomosis: The artery ends may be anastomosed without interposing a vein graft if the excised artery segment is short (less than 2 cm). There must be no tension along the suture line! You may mobilize the artery ends to some extent by soft tissue dissection along the artery in both directions. But extensive dissection will damage collateral vessels and the nutrition to the artery wall itself – and increase the risk of secondary rupture of the anastomosis. If you are in doubt, it is safer to use graft-anastomosis (p. 192). First apply the two stay sutures as illustrated.

12

12 The vascular suture: In major- and medium-sized vessels close the anastomosis with continuous over-and-over-sutures 1-2 mm from the edge, and 1-2 mm between each suture. Your assistant pulls slightly each suture while you apply the next. Use two separate sutures: one for half the circumference, the next one for the other half. Wash the artery and remove all clots before you close the anastomosis, tying the two sutures together with at least five knots so that they do not slip. **Notice:** Include all layers of the wall in each suture, or the intima will escape and prolapse into the lumen. **Notice:** Take care that the needle penetrates 90 degrees to the artery wall, and apply each stitch at very regular intervals. Control the suture line: Release the clamps slowly, first the distal one, then the proximal one. Some leaking in the suture line is not uncommon. Compress slightly with dry gauze for two minutes. If it still leaks, add some interrupted sutures at the leaking points.

13 Anastomosis of small-caliber arteries: Continuous sutures will cause constriction at the suture line. Better use interrupted sutures, either plain or mattress sutures as illustrated.

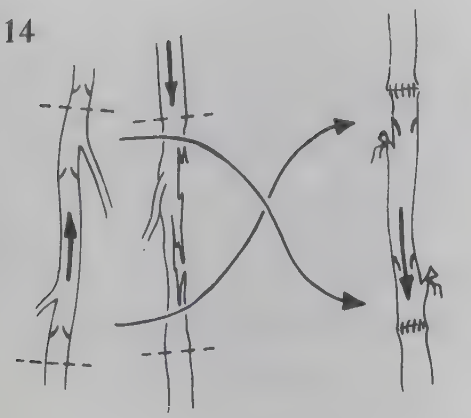
Debride and drain the wound track: Infection at the site of vascular repair is a catastrophe. Debride and drain the soft tissues very carefully close to the reconstructed vessel.

Drain and cover the anastomosis: A hematoma will cause infection as well. Some leaking at the suture line is common; you should drain the site of

Common muscle flaps: see Index.

vascular repair separately. Place a soft tube drain at level with the vascular su ture, but take care that it does not press directly upon the vessel. Avoid gauz drains as they may tear the sutures when you remove them. Adapt the deep l er of muscles in the exploratory incision with a few interrupted sutures to cover the anastomosis. Leave both the wound track and the superficial part o the exploratory incision open. If there is loss of soft tissues, well-circulated local muscle flaps are mobilized to cover the vessel.

14

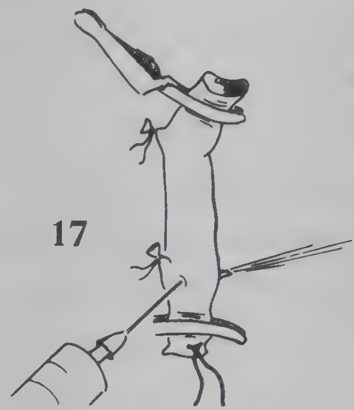


14 Anastomosis with interposed, reversed vein graft
If the injured segment is more than 1-2 cm wide, interpose a graft to avoid te sion on the suture line. The vein graft should be slightly longer than the excis segment of the artery. Due to the valves inside the vein, the graft must be reversed to avoid obstruction of the blood flow.

15

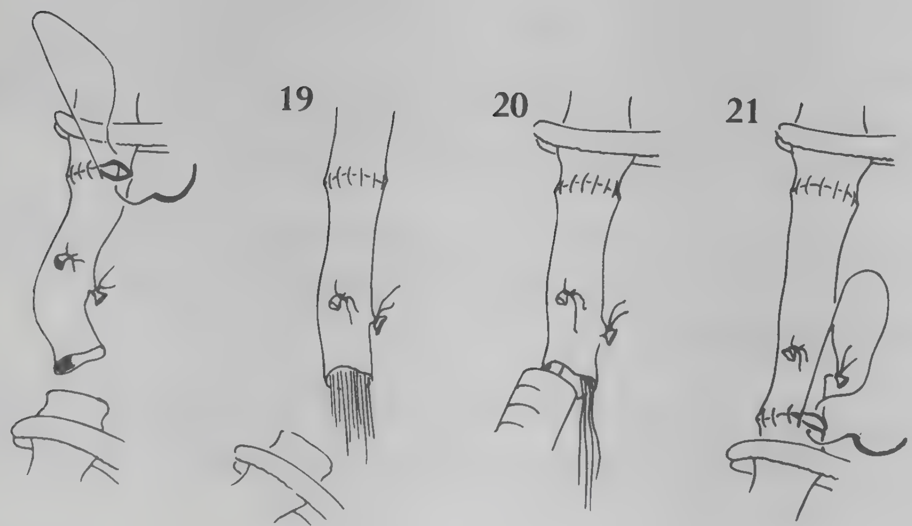
16

17



15, 16, 17 Preparation of the vein graft: The opposite leg's great saphenou vein is suitable for a variety of arteries (ill 20 below). The small saphenous ve and the lateral arm vein may also be used. Isolate the vein by careful dissectio identify and ligate all small side veins. Take care that the ligatures are applied correctly. Before you remove the vein graft, tie a long mark suture to its distal end to secure that this end is for the proximal anastomosis. Test the vein graft by clamping each end and injecting normal saline into the graft lumen (do not distend it too much). Tie the side veins that are leaking.

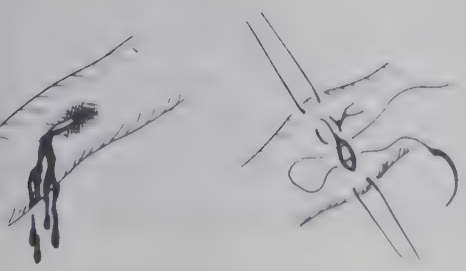
18 19 20 21



18, 19, 20, 21 The grafting techni que: The suture technique is identi- cal with that of direct anastomosis (il 11, 12 above). When the proximal anastomosis is done, remove the proximal clamp to check the blood flow. Wash blood clots from within the graft. Local heparinization: Instil heparin-saline solution (50 IU/ml) proximal to the graft. Before you proceed with the distal anastomosis, release the distal clamp and check the back-flow. If it is poor, use the embo- lectomy catheter (ill 9 above).

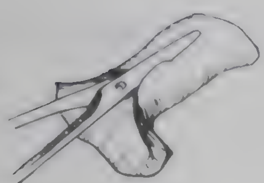
22 Matching the graft caliber: If the graft caliber does not fit the artery, you can adjust the circumference of either by cutting the end obliquely. The more oblique the cut, the bigger the circumference.

> Artificial vascular grafts are available (Gortex or Dacron). They need no preparation and will reduce the time of operation. But they are expensive. They have a higher rate of occlusion than venous grafts in medium- and small-caliber arteries. Dacron grafts should be avoided in infected areas. Gortex grafts resist infections as well as the vein grafts.



23 Suture of small side-hole injuries: A very small tear or puncture wound in a major- or medium-sized vessel may be sutured directly. In order to avoid constriction of the vessel at the suture site, a longitudinal tear is converted to a transverse tear between stay sutures before suture.

24



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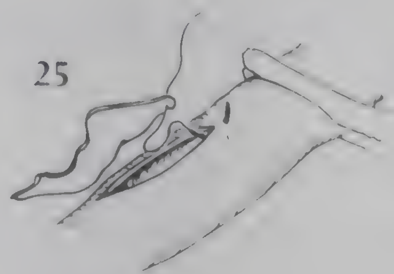

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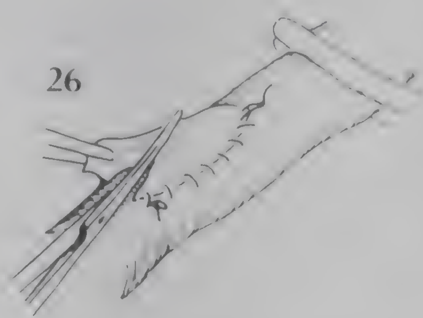

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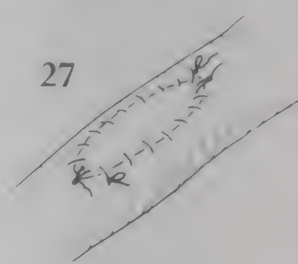


24, 25, 26, 27 Major side-hole injuries – reconstruction by vein patch: A more than minor side hole should be reconstructed either by excision and end-to-end anastomosis, or by vein patch. First debride the edges of the artery tear. Check that the intima is in position; any prolapse of intima should be debrided and the edges of intima fixed by sutures. Then collect a short vein graft and split the vein at a segment where there are no valves. Trim the patch to roughly fit the tear, and insert the first suture in the corner of the tear. Fix one side of the patch by the first suture. Trim the patch again, and fix it by a second continuous suture.

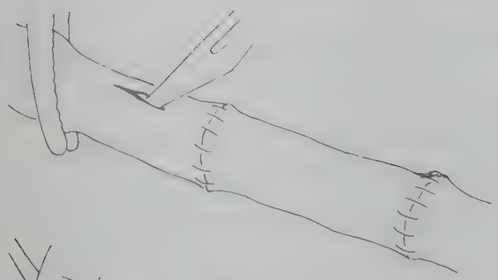
Complications of vascular surgery

Thrombus formation – urgent surgery

Monitor the distal circulation every hour after vascular surgery. The distal pulse volume may diminish. As long as the capillary circulation (skin temperature, skin color, capillary refilling time) is good, do not worry. But if both the capillary circulation and the pulse volume decrease within 24-48 hours after the operation, reoperate without delay! The likely reason is thrombus formation and/or intimal prolapse. If fasciotomy of all muscle compartments was not

done during primary surgery, do it bed-side and observe the distal circulation. If it improves within 30 minutes, compartment syndrome was the reason for circulatory collapse. If it does not improve, embolectomy is indicated.

28



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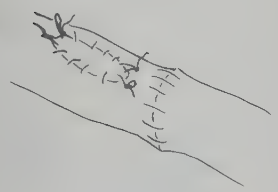

28, 29, 30 Embolectomy: Reopen the incision and control the artery proximal and distal to the anastomosis. Make a small arteriotomy. Insert the embolectomy catheter and remove clots in both directions until you get good rebleeding. If you feel some resistance inside the lumen when you insert the catheter, do not force it. There may be an intimal prolapse partly obstructing the lumen. Extend the arteriotomy or make another, explore the lumen and fi the intima with some interrupted sutures. Then close the arteriotomy incision release the distal and the proximal clamp and watch the circulation in the dista part of limb for some minutes. If the distal circulation now improves, adapt th soft tissue cover. If not, re-explore the vessel in both directions until you have identified and managed the cause. If that is not possible, this is a case for amputation. **Notice:** Transverse arteriotomy incisions should be used on limb arteries to prevent stenosis.

The second thrombosis
Continue close monitoring after embolectomy. A second thrombosis event is a reason to amputate.

Hematoma at the site of repair

- **Early hematoma:** Most hematomas develop during the first 24 hours after surgery. The main reason is leaking at the suture line. As hematoma implies infection, and the drainage evidently is insufficient, reoperate before the infection may develop. Wash the site of repair well, apply hemostatic sutures and drain properly.
- **Late hematoma:** Hematoma formation days and weeks after the primary surgery is probably due to local infection in necrotic tissue left over after an inadequate debridement. Also consider failure of the coagulation system as a reason for rebleeding. Anyhow, the risk of sudden massive bleeding is high if the hematoma is not evacuated.

Coagulation system failure: p. 593.

Before you enter the hematoma, apply a proximal cuff-tourniquet in case of heavy bleeding – but do not inflate it until there is no way out. Wash out the hematoma and explore the vascular suture. If leaking, first apply gauze pressure for 10 minutes; hemostatic sutures may cause more bleeding instead of controlling it. If it still leaks, try some fine-caliber hemostatic sutures. Also explore and redebride the soft tissues. Is the soft tissue cover sufficient? Transposition of a well-circulated muscle flap is the most efficient measure to control oozing of blood and low-grade local infection.

Secondary massive bleeding

It happens within 4-14 days after the primary surgery, starts suddenly and may be fatal. The reason is local infection. The management is emergency amputation.

Points to note – Chapter 11

The main problem is the soft tissue damage at the fracture site
- note how fractures heal: p. 199
- study why open compound fractures should be especially well debrided and drained: p. 80 and 179
- use the Trueta plaster method for both drainage and fracture fixation: p. 182 and 208
- note the vascular anatomy of soft tissue flaps: p. 200 and 255

Train in plastercraft
- it is the soft tissue pressure that supports the fracture: p. 204
- know when to use plaster-and-pins for fracture fixation: p. 209 and 526
- notice how "a compartment syndrome" may form inside a circular cast, and how to prevent it: p. 206 and 521
- train in applying well-fitting, light-padded standard casts on the upper limb: p. 205 and 505. And on the lower limb: p. 206 and 535

Traction management
- note the drawbacks of traction management: p. 211
- study how dynamic traction is done, and how it is monitored: p. 213

Some fractures heal slowly, or don't heal at all
- know the reasons why: p. 214
- train in orthosis fitting: p. 215

Study the particular features of common fractures
- fractures of the arm: p. 489 and 491
- the forearm fractures: p. 505
- fractures at the hand and fingers: p. 506
- pelvic fractures: p. 477
- upper and mid-thigh fractures: p. 524
- fractures at the knee joint: p. 534
- lower leg fractures: p. 544
- fractures of the calcaneus and talus: p. 547

Training of muscles and joints stimulates fracture healing
- know how to set up a rehabilitation program: p. 628
- know the common physical exercises: p. 631
- note how to make and use simple walking aids: p. 636

11 Fractures

Types of fractures

Exact documentation at the site of injury should be done by the medic first seeing the patient. Information on the actual soft tissue damage, the degree of bone fragmentation, the position of the bone fragments are essentia for further surgery. The best front-line report may be a simple sketch and some words for explanation.

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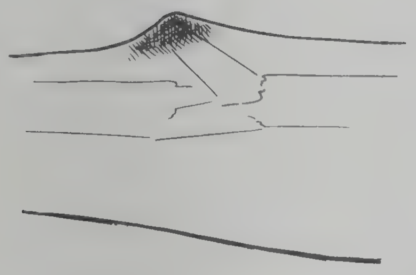

1 Describe: Open or closed fracture.
The closed fracture: The skin and subcutaneous tissue in the fracture area remain intact. The closed fracture poses no serious problem regarding infection and heals well. **The open fracture:** The skin and soft tissue covering the fracture area are damaged either by the missile, or by protrusion of bone fragments. Classify the fracture as open also if some bone fragment presses upon the skin and thereby causes discoloration of the skin – even if there are no ope wounds of that area. To avoid infection in open missile fractures is one main challenge in wartime surgery.

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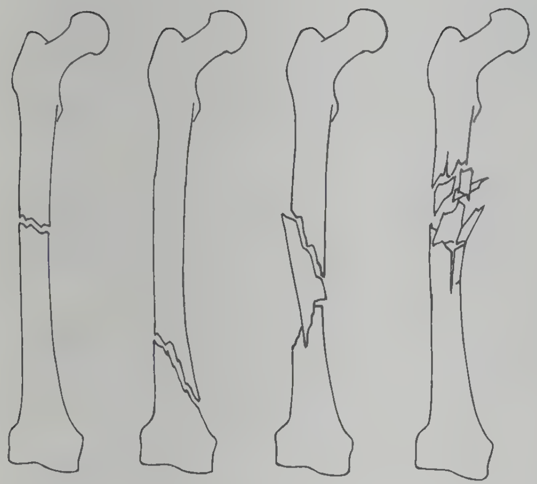

Describe: The fragmentation of the fracture.

2 A simple transverse fracture.

3 An oblique fracture.

4 A segmental fracture with one large intermediary fragment.

5 A comminuted fracture. This type of fracture is a sign of high-energy missile hit. The more comminuted it is, the higher the energy absorbed from the missile.

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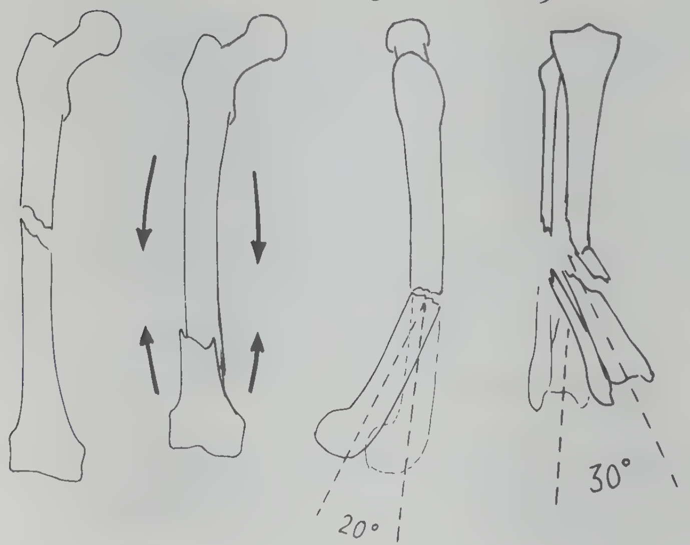
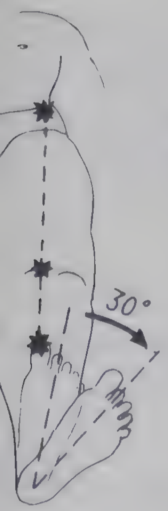


6 Describe: The fracture position. Here distraction (or bone loss).

7 Fragments overlap or impaction.

8 Describe: The angulation – side-view: Describe the angulation of the **distal** fragment seen both from the side and from the front. In this case: femur shaft fracture with dorsal angulation of 20 degrees.

9 Angulation – frontal view: Distal tibial fragment with medial angulation of 30 degrees.



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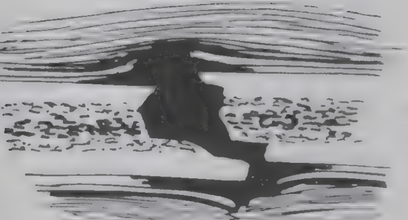
10 Describe: The rotation of the distal fragment. In this femur fracture the distal fragment is in 30 degrees external rotation.

11 In this 3rd finger fracture the distal fragment is in radial rotation of 20 degrees.

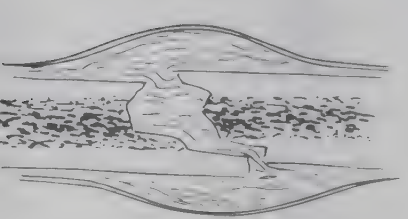
Healing of fractures

The bone is not a dead or static structure; instead a continuous process of resorption and new bone formation is going on in all parts of the skeleton. The bone tissue is continuously resorbed into the bone marrow by bone-eating cells lining the inner side of the long bones. On the outer side, under the periosteal sheath, the bone-producing cells continuously form new bone. By this absorption-formation balance, the internal architecture of each bone is formed and maintained. Several factors determine the speed of bone regeneration:

- **The age of the patient:** In children the bone regeneration is faster than in adults. In elderly persons it is considerably slower than in adults – especially so in elderly women. **Notice:** In children less than 16 years of age the epiphyseal growth zone will react to a fracture with increased activity, that is, a fracture overlap (ill 8 above) of 1-2 cm at the time of injury in a femur fracture in a young child is acceptable. That child will regain the overlapped length after two years and end up with both femoral bones of equal lengths. The same goes for any other fracture of a child's long bone. In a child near 16 years, the growth activity is less; do not allow fracture overlap in that child.
- **Soft tissue injury:** The regeneration of bone depends mainly on the periosteum and therefore on the soft tissue state in the fracture area. Good soft tissue care is the main goal in wartime fracture surgery.
- **Infection:** In the presence of infection the fracture will heal badly. Often the reason for delayed healing is a low-grade infection in the fracture.
- **The general condition of the patient:** The bone formation is slow in malnourished patients, in multi-injury patients and in inactive patients with serious mental depression.
- **External stimulation enhances the healing process:** Training of the muscles in the fractured limb stimulates the blood circulation and the remodelling of bone. Careful weight-bearing will also stimulate new bone formation and the sound remodelling of bone.



12 Healing of fractures: At the time of injury the periosteum and minor blood vessels are broken. There is a fracture hematoma from which new bone will develop.



13 Within one month – the callus stage: Non-mineralized waxy bone called callus is formed by bone producing cells that enter the fracture hematoma. Gradually the callus transforms the hematoma into a waxy bridge. Callus formation increases and forms a "callus tumor" which you may identify through the skin. The fracture fragments become fixed inside the callus tumor. The fracture is not yet rigid, but elastic when you bend it carefully. The callus stage

may last from 1-3 months depending on which bone is broken. In cases of delayed union it may last up to one year. During this stage partial weight-bearing accelerates the bone formation. The periosteum is well innervated. The training load should therefore be regulated by the **pain signal:** A too heavy load will produce periosteal pain – reduce the load then.

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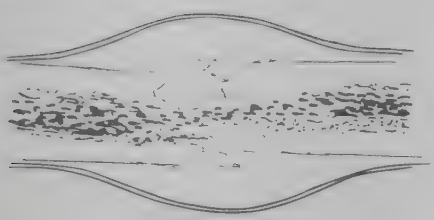

14 Within 2-3 months the bony consolidation starts: The callus is gradually mineralized and transformed into solid bone. Now that the fracture is stable and not elastic by manual testing, increase the training load.

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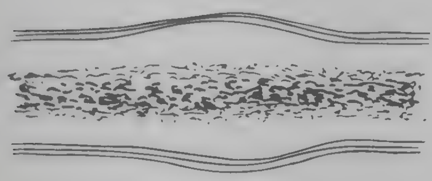

15 During 1 year – remodelling of the bone: The bone-eating and the bone-producing cells will gradually remodel and approximate the bone to its former shape. The internal architecture of the bone is also partly restored. This reconstruction process is finished 12-18 months after the injury.

Soft tissue flaps

The management of fractures with extensive loss of soft tissues is difficult. On the one hand, all non-viable soft tissues – without compromise – have to be removed at the primary debridement. This may leave wide soft tissue defects in the fracture area. On the other hand, exposed denuded bone inside the wound will inevitably become infected; the fracture needs nutrition from viable soft tissues in order to heal and to prevent infection . By soft tissue flaps you may overcome this problem: During the primary surgery mobilize viable soft tissue from around the fracture to cover the defect left after the debridement.

There are several types of soft tissue flaps:
- **Either adapt muscles** to cover the fracture. In minor soft tissue defects, this may be possible.
- **Or raise a full thickness skin flap** to cover the fracture. This may be possible in minor defects in the forearm and lower leg.
- **Or mobilize rotation muscle flaps or muscle-skin flaps** to cover the fracture. The flaps may be rotated onto the fracture at the time of primary surgery. Or you may apply a two-step procedure: Debride the fracture wound and raise the flap at the time of primary surgery – but leave the flap in its bed until a secondary operation after 4-5 days. Then check the debridement, control the flap circulation, and rotate it onto the fracture. The viability of a skin-muscle flap depends on good vascular supply and venous drainage through the base of that flap. Thus you have to know the local vascular anatomy; design the flaps carefully and mobilize them with care and without tension so as not to damage their vascular network. There are several standard skin-muscle units throughout the body that are useful as rotation flaps to cover open fractures as well as open-joint injuries.

The local muscle flaps in detail – see Section 4:
Shoulder and arm: p. 491
Elbow: p. 498
Forearm: p. 498
Thigh: p. 525
Knee: p. 534
Lower leg: p. 544
Foot: p. 547

16

16 The muscle rotation flap in principle: The flap is raised through a separate incision over the muscle to be used. The muscle belly is mobilized by blunt dissection, and cut at a convenient length (dotted line). Note that the muscle will contract when you cut it. By blunt dissection, a tunnel is made towards the defect and the muscle flap delivered through that tunnel. The flap incision is closed, and the muscle flap covered by a split-skin graft. The skin grafting may be delayed for 4-5 days.

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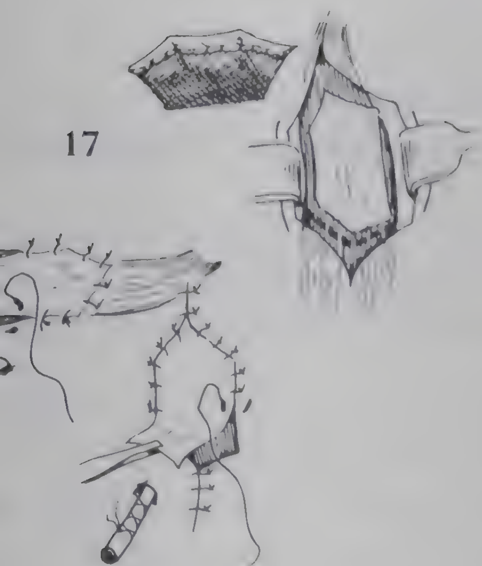

17 The skin-muscle rotation flap: By the same procedure the skin, subcutaneous fat, fascia and muscle are raised and rotated in one piece. The remaining defect at the flap donor site is covered by skin grafts.

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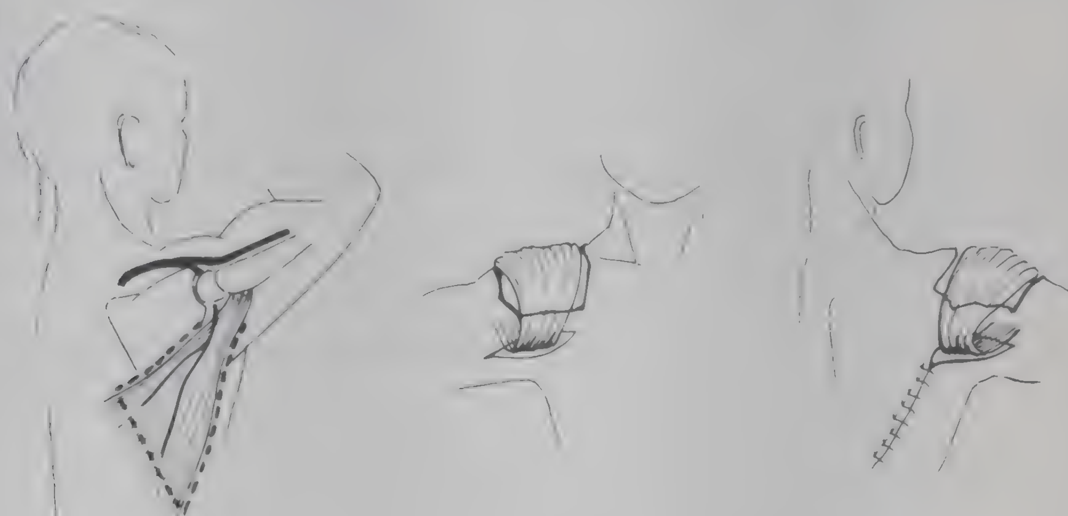

18 The latissimus dorsi flap covers major defects of the axilla, shoulder and upper arm. Vascular supply is from the thoraco-dorsal artery. The deltoid, biceps and triceps flaps all have a rich vascular supply but their range is restricted. Forearm and elbow fractures: From both the flexor and extensor muscles the superficial muscle bellies may be raised to cover soft tissue defects.

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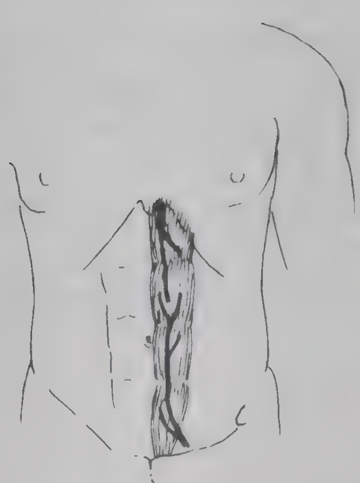

19 The rectus abdominis flap: This long muscle belly receives its vascular supply from above (the superior epigastric artery), and from the groin (the inferior epigastric artery). You may thus design flaps with either proximal or distal base. The flaps have a wide range and can be used for lower arm injuries as well as defects of the chest wall, abdominal wall and upper thigh.

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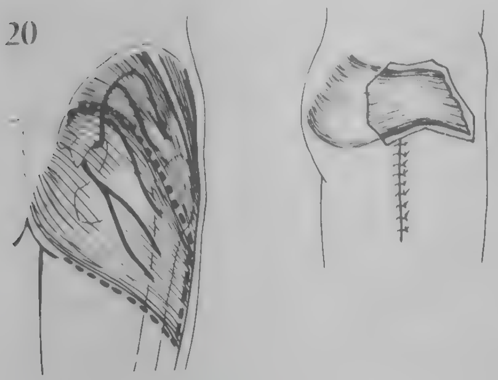

20 **The gluteus flap:** The flap is well vascularized from the superior and inferior gluteal arteries, but its range is restricted. Still it is useful as missile injuries of the buttocks often indicate wide debridements (p. 473).

Joint protection

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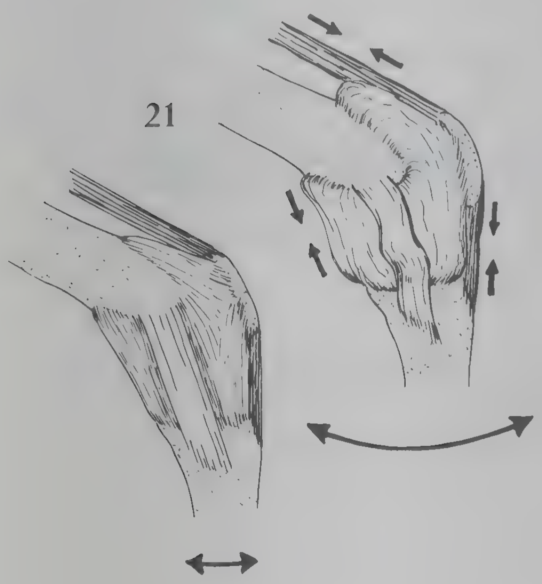

The neutral position is the position with the least risk of permanent joint damage through capsule-ligamentum contracture.

21 **Prevent contractures:** Any joint capsule, ligament or tendon will shrink and become stiff when not used. After four weeks' immobilization in plaster the process of joint and tendon contracture becomes a real problem. Even with daily intensive training, a joint immobilized for four weeks may never regain normal function. Extensive soft tissue damage around the joint further increases the risk of joint contracture.

- **Always immobilize the joints in their neutral positions:**
  – The elbow: Slightly extended from 90-degree position. Neutral forearm rotation.
  – The wrist and hand: The wrist joint slightly extended, the MCP joints in 90-degree flexion, the two distal finger joints as extended as possible.
  – The knee and ankle: The knee approximately 20 degrees flexed. The ankle exactly 90 degrees flexed.
  – The foot: Look at the toes and foot end on. Not any degree of rotation should be accepted. Take care to evert the outer edge of the foot.
- **The time of immobilization must be as short as possible:** When bony consolidation is established and the fracture is semi-stable, change the primary plaster cast into one which does not immobilize the joints. Or apply an orthosis (see below).
- **Apply dynamic traction instead of static traction wherever possible.**

Battlefield management

Immediate reduction!

Every fracture, open as well as closed, should be reduced as soon as possible after injury. Malposition of bone fragments during evacuation will add to the soft tissue injury caused by the missile. Early fracture reduction improves the local circulation, reduces pain and improves the general condition. During the first 1-2 minutes after the injury, manipulation of the fracture is less painful, and any fracture may be aligned without anesthesia. Reduction more than two minutes after the time of injury, should be done in local anesthesia (10-20 ml lidocaine injected into the fracture hematoma; or low-dose i.v. ketamine anesthesia).

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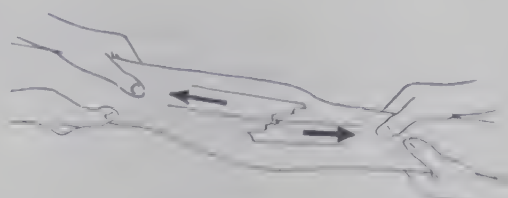

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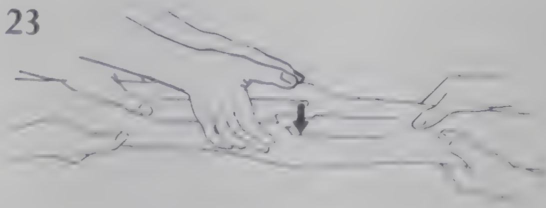
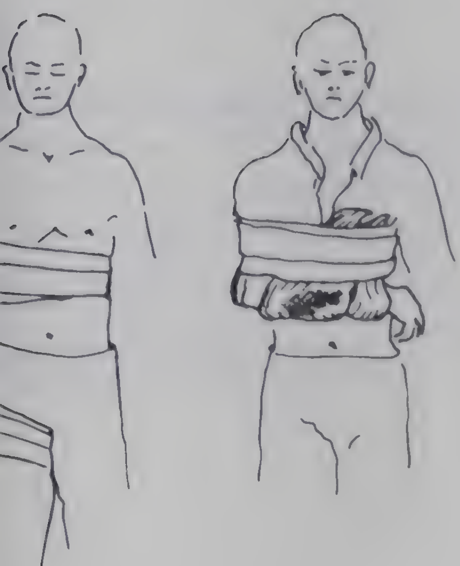


22, 23 Fracture reduction: The only safe procedure for fracture reduction is manual traction. Pull the distal fragment (foot or hand) in the limb direction. In most cases this traction alone will reduce the fracture roughly. A major bone fragment dislocated through the wound should be grasped and repositioned directly. Do not worry about sterility – the wound is dirty already. If the fracture is some hours old there may be a considerable overlap in the fracture. Let one assistant pull steadily for one minute. Then, still under traction, reduce the fracture by molding it.



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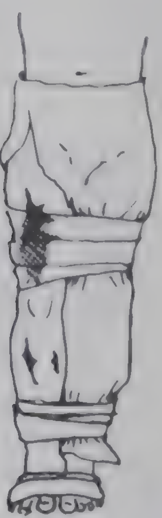

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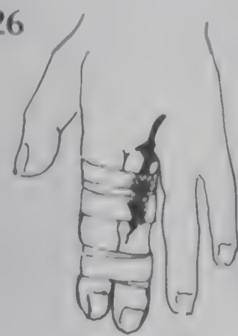


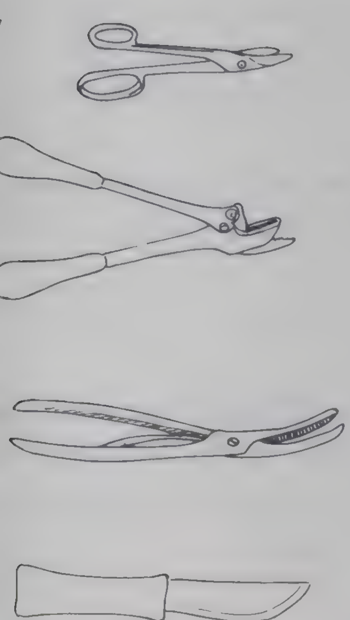
24 Stabilize the fracture with any means at hand – use the body as splint!

25 Use the opposite leg as splint!

26 Use the neighboring finger as splint!

Plastercraft

> **Never** treat an open wartime fracture with internal fixation (plate/screws, intramedullary nailing, transosseous pinning through the fracture area etc). Internal fixation causes wound infection and osteomyelitis.
> **Always** use external fixation in wartime fractures. The alternatives are many: plaster cast, plaster cast combined with bone pinning, traction, external fixation apparatus, orthosis.



27 The essentials for plastercraft: plaster shears, small and large. (You may make it with a knife.) Cast-bending forceps. Plaster of Paris, rolls of 10 and 15 cm. Water. Cotton for padding. A fat ointment to fix the padding to the skin. At least one skilled assistant – and lots of training.

- **Before you start:** Instruct your assistant about the actual plaster, the direction of traction, the joint positions, the molding of the plaster etc. Wash the

actual limb. Dirt or small particles of gypsum under the plaster may damage the skin. Then take measures and prepare the plaster slabs and plaster rolls you need. All materials must be ready and at hand before the application starts.

- **The padding:** The main point of plaster immobilization is molding of the plaster so that it fits the limb like an elastic stocking with an even pressure against the soft tissues all along the limb. Too much padding prevents good molding!

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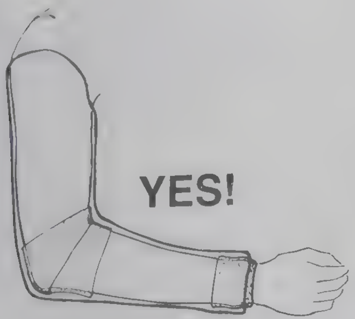

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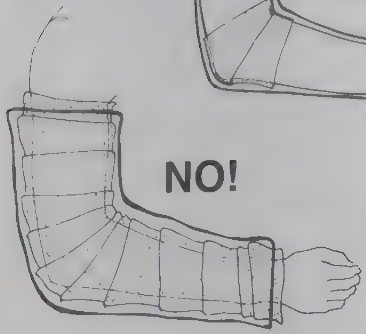

28 **A well-fitting plaster:** Thin padding just over the bony prominences.

29 **An ill-fitting plaster:** The padding creates an uneven pressure against the soft tissues. This actually obstructs the venous circulation and may cause limb edema.

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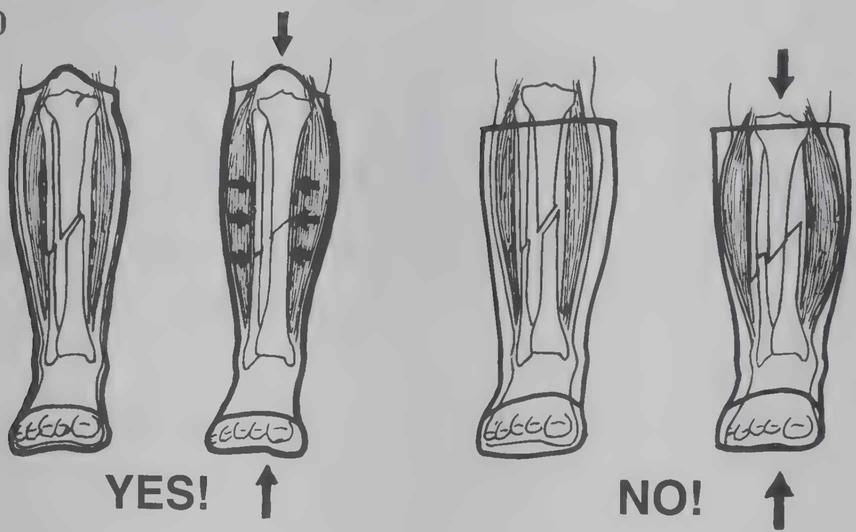

30 **The soft tissue pressure fixes the fracture:** If the cast is wide with thick padding the pressure is not evenly distributed along the shaft of the bone – and the fracture will displace. Mold the cast to fit the contours of the muscles like a stocking.

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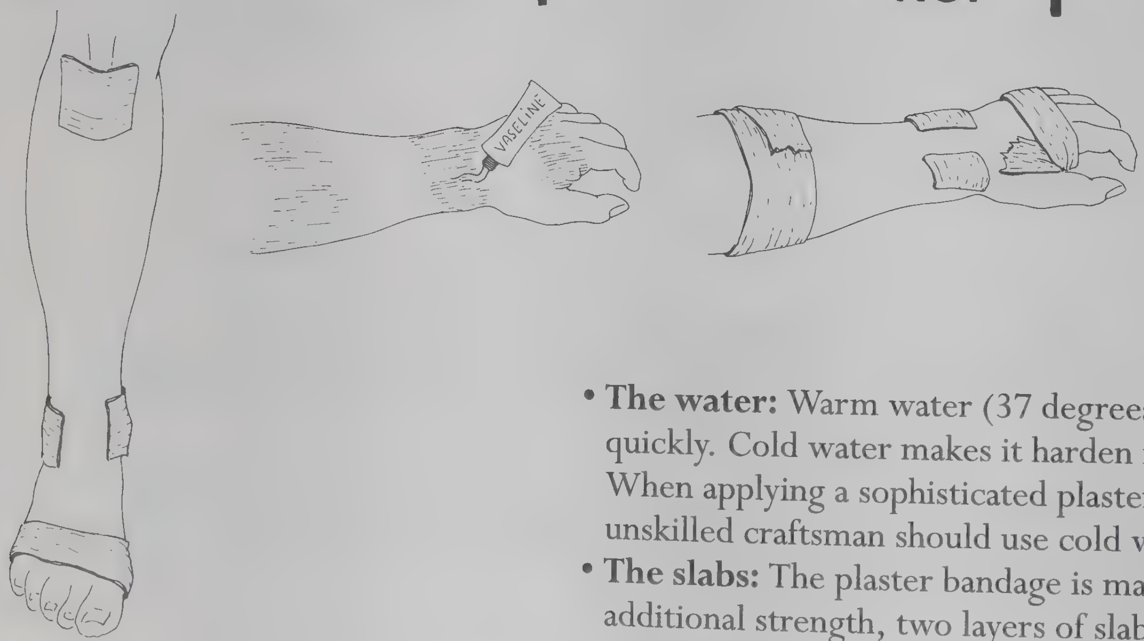

31 **Correct padding:** Ointment on the skin over the bony prominences will fix the cotton pads. Thin strips of filter or cotton is sufficient padding – provided that the cast is well molded to fit every contour of the limb.

- **The water:** Warm water (37 degrees C) makes the plaster of Paris harden quickly. Cold water makes it harden more slowly(after 5 - 10 minutes). When applying a sophisticated plaster bandage, use cold water. Also the unskilled craftsman should use cold water.
- **The slabs:** The plaster bandage is made out of **slabs** and **circular turns.** For additional strength, two layers of slabs with circular turns between them may be applied.

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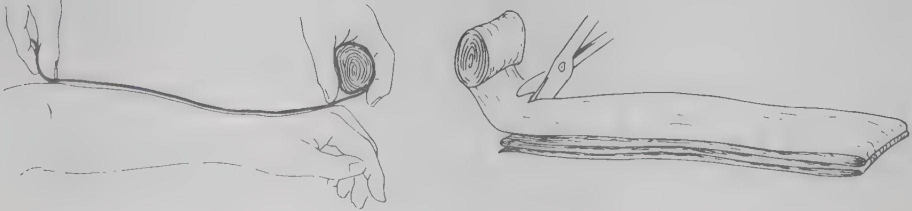
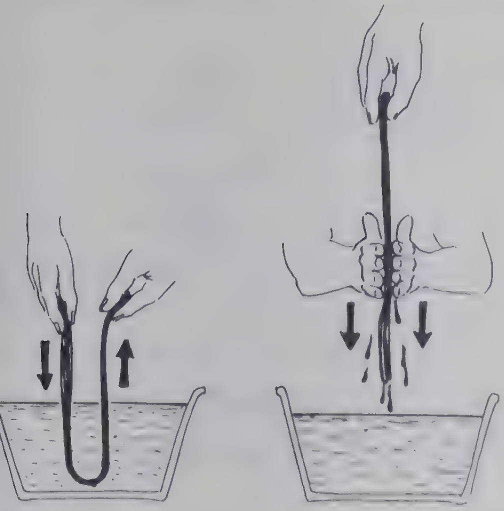


32 **The slab length:** Measure the length of the slab on the limb. Add 5-10 cm for the expected shrinkage of the slab when wet.



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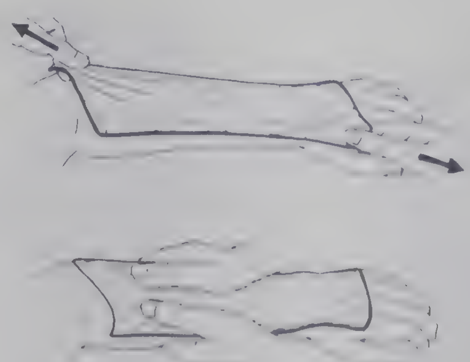
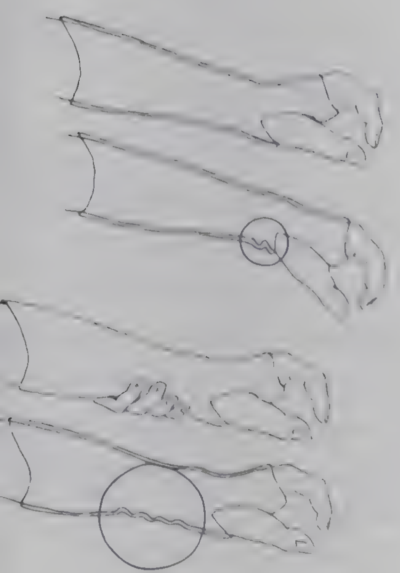


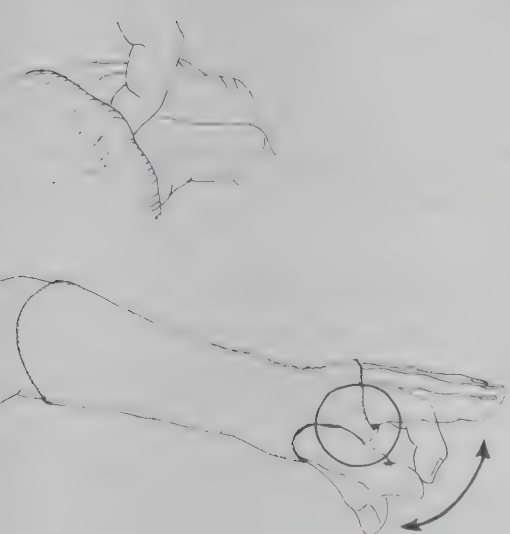
33, 34 The application: Pull the slab through the water once. Hold it up at one end and let it drip water. You may let your assistant carefully wipe off the excess water from the slab. Stretch the slab ends until they are in the correct position. Then mold the slab onto the skin. **Notice:** No bends and folds on the slab!



35 Warning: From now on until the cast is stiff, the joints must not change position in order to avoid bends inside the plaster that may create skin damage or obstruct the venous circulation. The assistant should not leave fingerprints on the plaster, for they will cause pressure wounds under the plaster.

36

36 The circular turns are made of plaster rolls 10 or 15 cm wide. Put the roll into water. Keep it there until air bubbles do not leak out from the roll. Then take the roll out of water and press it slightly for water. Too much pressure will remove the plaster from the gauze. Work clockwise (if you are right-handed) from the distal towards the proximal part of the limb. Stretch each turn with your left hand. Avoid folding of the bandage by smoothing the surface between each roll applied. Plaster strength mainly depends on even application and good molding of the plaster. A thick and heavy plaster bandage is not necessary and will create problems during the rehabilitation.



37 Before the cast hardens: The plaster hardens through a chemical reaction inside the plaster. After some minutes you will feel the plaster becoming warm. Before the temperature rises, smooth the outer surface of the cast. The smooth surface makes the plaster stronger and more resistant to damp and water that would soften and damage the cast. Also smooth and lift slightly the edges of the cast so they do not press upon the skin when edema develops. Test the joint movement proximal and distal to the cast; check that the joints not immobilized are really free. **Notice:** The hardening process lasts for 24 hours. During this time the plaster should not carry any load or be covered by blankets and clothes that may prevent its drying.

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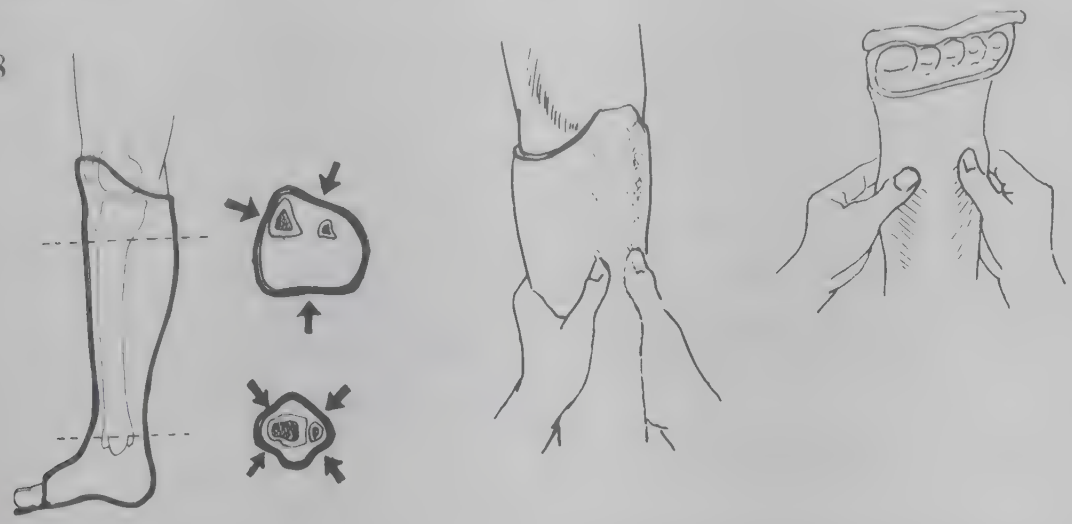

38 Mold the cast to prevent limb rotation: A Sarmiento patella-bearing cast is illustrated. Notice the cross section through proximal tibia with its triangular form, and the quadrate form of the cross section through the ankle. Mold the cast carefully to fit these forms. Also do the same for any other cast.

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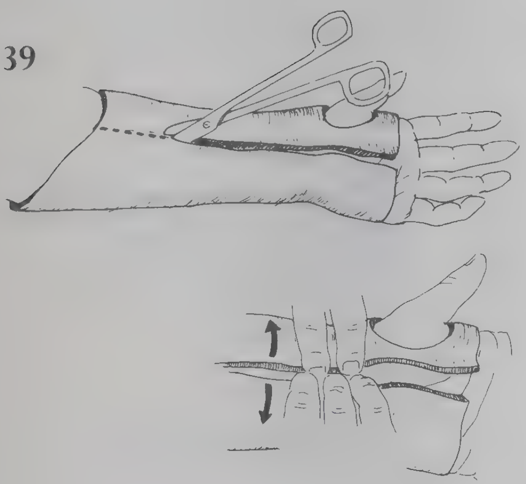

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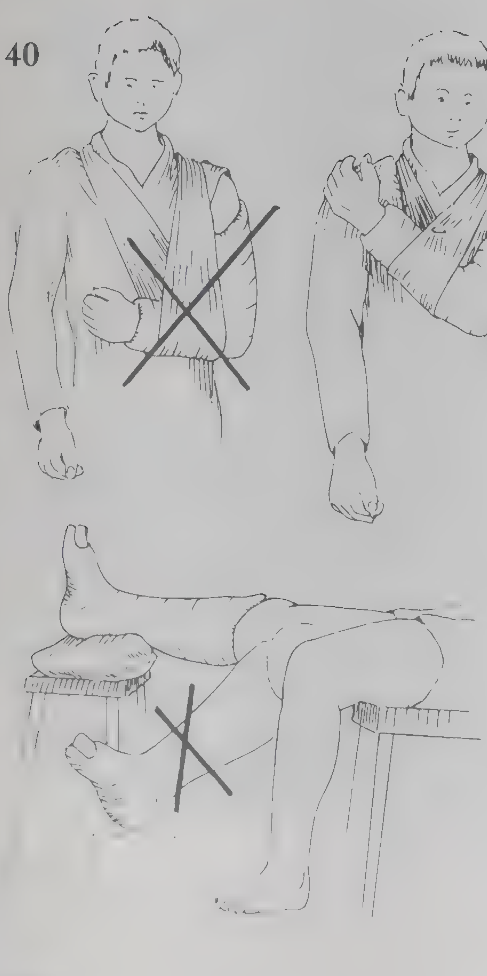


The problem of swelling inside the plaster cast – information for your patients

Edema always develops after injury, and rises to a peak 2-3 days after the injury or surgery. Inside a circular plaster cast edema will create a "compartment syndrome": Increased soft tissue pressure may obstruct the limb veins, gradually also the minor arteries. Serious damage to the limb nerves may develop due to lack of oxygen. If the pressure is not relieved in due time, a permanent condition – reflex dystrophy – may develop. For reflex dystrophy there is no effective treatment. Concentrate on preventing it, that is, on fighting the edema problem.

The signs of increasing edema inside the cast

- Swelling distal to the cast
- Cyanosis distal to the cast
- Sign of alarm: Increasing pain inside the cast at even slight movement of fingers/toes

Prevent edema complications by

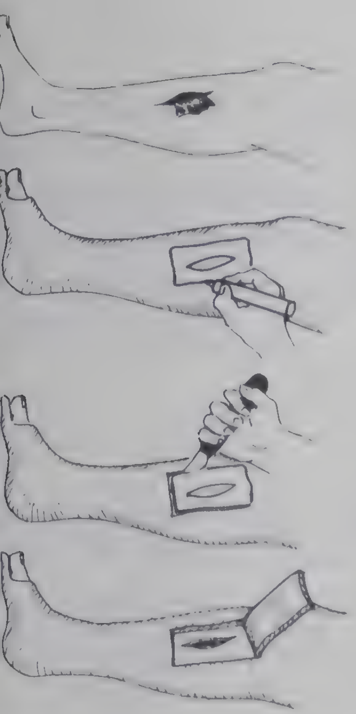
- **39** Longitudinal splitting of the plaster bandage in patients where much edema is expected
- Delaying the plaster application until the 3rd-4th day after the injury.
- **40** Elevation of plastered limb
- Active exercises with isometric muscle training inside the plaster – provide efficient analgesia!

Cyanosis and/or increasing pain
→ split the cast immediately! If the edema does not recede:
→ remove the cast and consider fasciotomy!

If you act too late – these are the signs of reflex dystrophy:

- Pain far exceeding the normal, lasting for days and weeks
- The skin gradually becomes glossy, thin and painful at the slightest touch
- The limb becomes edematous
- The joint movements are restricted and painful

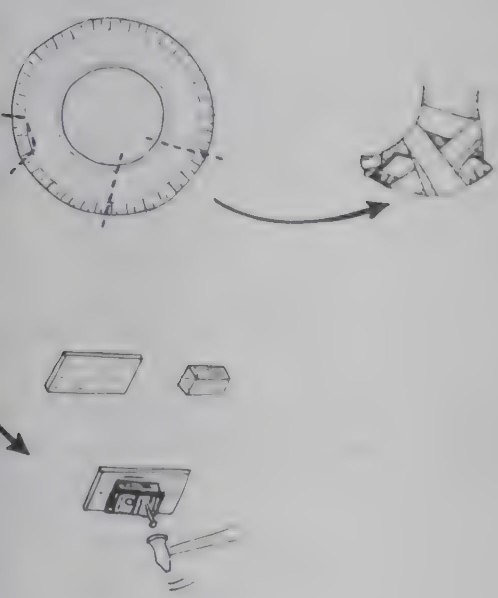
The problem of pressure wounds under the plaster: A well-fitting plaster should relieve the patient of much of his pain and generally improve his condition. If the patient complains about localized pain under the plaster, this may be a sign of localized pressure on the skin from a bad-fitting plaster: Release that plaster – look for pressure injury. A pressure wound may induce the the reflex dystrophy. So never ignore the complaints from your patients. Ask if they feel lasting and localized pain under the plaster.



41 Plaster with window: If you want to monitor an open fracture, make a wound window in the plaster cast. Mark the exact location of the window, and cut it with a knife when the plaster is hardened. Fix the window with crepe bandage between the dressings. **Notice:** The window weakens the plaster cast, and makes it less efficient as fracture fixation. Consider the Trueta plaster as an alternative (p. 208).

Walking plaster?

Early partial weight load upon the fracture will promote the healing of the fracture. You may apply a walking heel or boot 1-2 months after injury depending on the actual fracture. Test the fracture: Does it resist manipulation? Is it stiff? Is there no pain when you press the fracture line? Then bony consolidation has started, and weight-bearing up to the limit of fracture pain can start.



42 Walking heels – ready-made ones are available. You may as well use sections of a tyre applied as a boot (pad inside the tyre). Or a tyre patch fixed to a small wooden plate as a walking heel.

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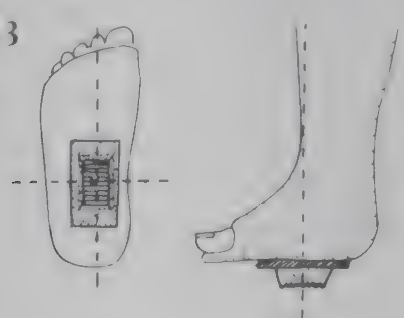
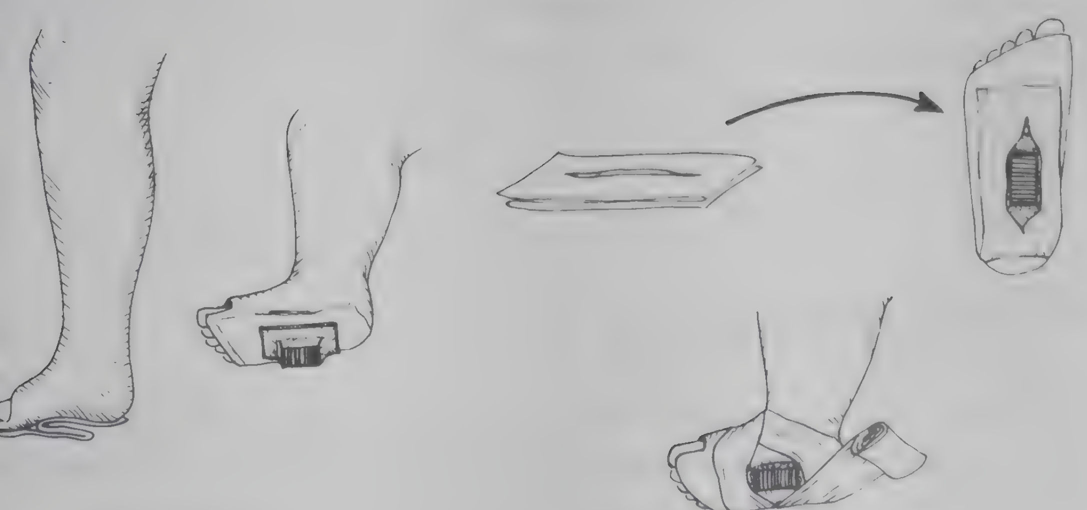


43 Applying the walking heel: Locate the heel exactly – its center should be slightly in front of the axis through the tibia. Also look the foot end on and locate the heel under tibia, that is slightly to the medial side of the center of the foot.



44 Fill the foot profile with plaster to a straight plane. Make a short split slab for the heel. Fix the heel with additional circular turns of plaster.

The Trueta plaster method

In Barcelona Dr. Trueta managed 1073 cases with open compound gunshot fractures with this particular plaster technique. The rate of osteomyelitis was 7% and the mortality rate 0.5%.

We have named this method after the first war surgeon who really developed this method. The English war surgeon Joseph Trueta fully exploited the qualities of the plaster in the treatment of extensive war injuries during his duty in the Spanish civil war in 1938. The special feature of the Trueta method is to use the absorbent ability of a plaster cast in the drainage of major wounds.

The essentials of the Trueta method:

- **The plaster cast as drainage of soft tissue wounds:** The plaster of Paris has great suction capacity for blood and wound exudate. At the same time the plaster bandage is permeable to air, and therefore does not contribute to an anaerobic milieu with anaerobic infections.
- **The plaster cast as fixation of fractures:** The well-molded light padded plaster immobilizes the fracture.
- **The plaster cast as soft tissue support:** Trueta himself did hardly pad the limb before applying the plaster cast, but was very careful to mold the cast so that it exactly fitted the soft tissue contour of the limb. Thus the bandage also supports the injured soft tissues – it prevents edema, promotes venous drainage, reduces the pain, and thereby promotes the healing.

The practical procedure: p. 182.

Early skin grafting on open fractures promotes healing and helps prevent infection.

- **In open fractures:** A thorough primary debridement of the wartime wound is imperative for the Trueta method to work. In major open fractures we advice you to leave the limb without cast until 4-5 days after injury; then re-explore the wound to make sure that the debridement is complete before the Trueta cast is applied. The cast should not be removed until the fracture has some callus stability, that is 3-5 weeks after injury. When the wound is cleaned you will find nice granulations. The gauze drain is often attached into the soft tissues. By soaking the wound for 5-10 minutes with hydrogen peroxide the drain is removed. If the granulations are still not ready for grafting, another Trueta plaster may be applied for 1-2 weeks or the wound dressed 2-3 times daily with slightly hypertonic saline solutions to accelerate the granulation.
- **In extensive soft tissue injuries:** The cast is removed after 1-3 weeks depending on the depth of the wound.

External fixation

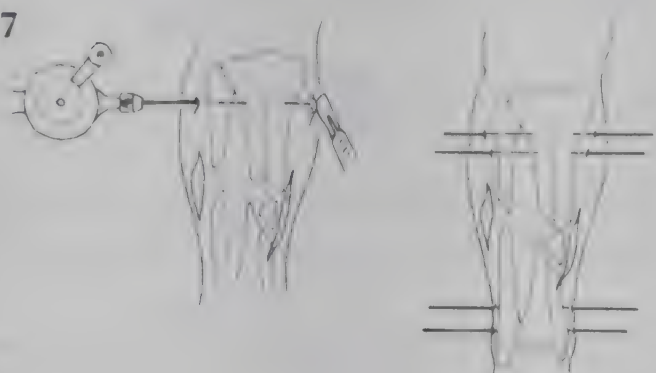
Even the best plaster cast cannot fix the unstable fractures – fractures with considerable loss of bone, very comminuted fractures, and fractures with extensive loss of soft tissues. Some method of external fixation is then indicated:

- **The plaster-and-pins method** provides good external fixation. The method is cheap, simple and rapid. And it may be combined with the Trueta method, making it very suitable for forward management of wartime fractures.
- **The external fixation apparatus** provides effective fracture fixation while you at the same time can work on his soft tissue injury. But the equipment is expensive.
- **Traction** is also a type of external fixation. The procedure is simple, but has a drawback in fixing the patient to his bed. Thus it makes exercises and active physical rehabilitation difficult – as well as evacuation when under military pressure. Do not underestimate the mental complications of total immobilization in traction for an exhausted war victim.

45 **Plaster-and-pins. Equipment needed:** Steinmann pins (2, 3 and 4 mm) or Kirschner wires (1.5 and 2 mm). Drill with chuck (a drill from a hardware store will do it). You may use a hammer on the Steinmann pins; the Kirschner pins must be drilled. Wooden plates approximately 3x10 cm.

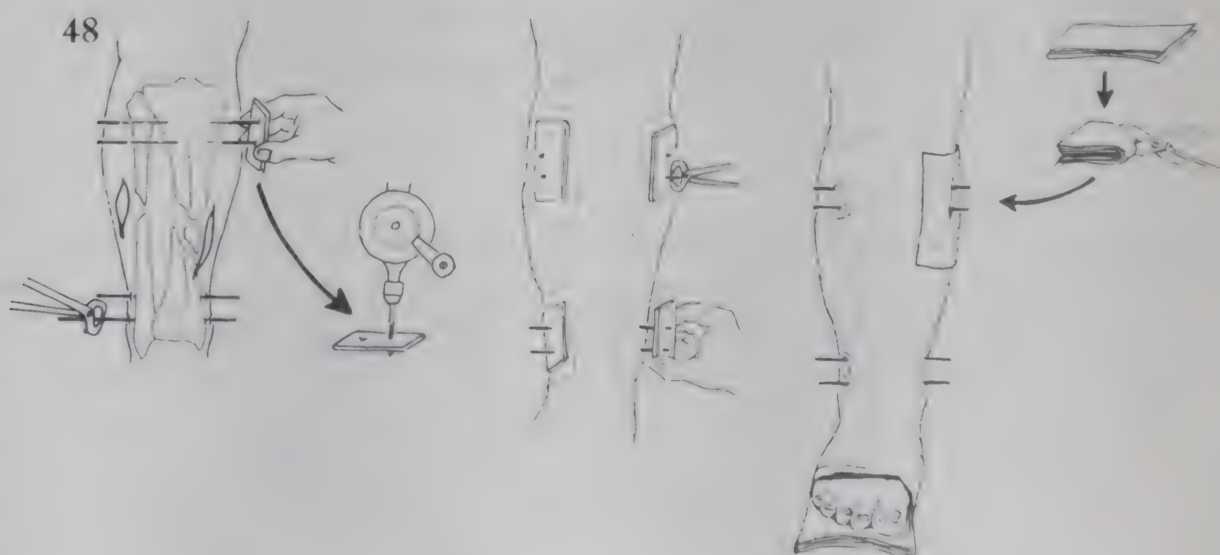
46 **The procedure – local anesthesia:** The pins must be inserted through viable soft tissues, outside the wound area. Wash the pinning area! Sterile gloves! The entire procedure may be done under local anesthesia: Infiltrate the pinning points on both sides with local anesthesia, including the periosteum.

47



47 **The pin insertion:** Drill (or drive with careful hammering) the pin through the proximal main fragment from the lateral to the medial side. (Watch the peroneal nerve!) Pin the distal fragment in the same way. **Notice:** Never insert the pins at an oblique angle.

48



48 **The pin fixation:** Drill holes in each wooden plate to fit the pins. Then apply the slab and the first circular turns of plaster. Put the wooden plates in position, and cut the Kirschner wires 1 cm outside the plates. Fix the wooden plates with small plaster slabs, and another circular turn of plaster to make a standard plaster cast supporting the pins.

Warning

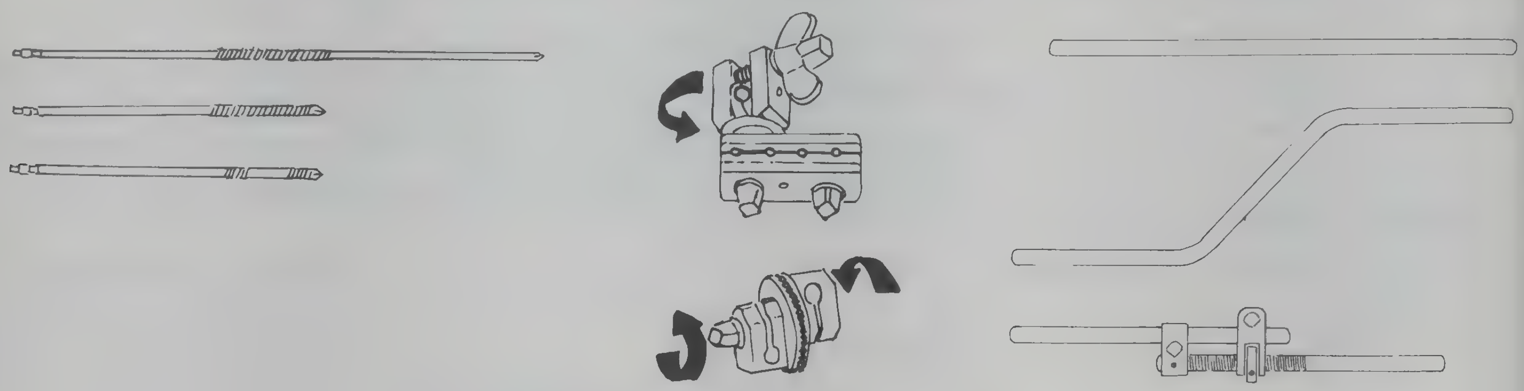
- When the pins are applied under sterile conditions we seldom see suppura-tion from the pins. But pinning into cancellous bone (trochanter or calcane often creates some irritation and even bone infection. Pins in these areas should be removed within four weeks.
- Never insert pins/wires through damaged or infected soft tissues.
- Do not insert pins through the bone growth zones (epiphyseal plates) in patients less than 18 years old.

The external fixation apparatus

Temporary external fixation: multiple bone pins with orthopedic cement-filled tubings as frame/connecting rods. Expired Simplex cement can be bulk purchased cheaply.

It is expensive, but locally produced improvisations can be made by any skille mechanic. The apparatus may seem complicated but is easy to apply. The mai advantage of this apparatus is the possibility for continuous monitoring of the soft tissue injury. The apparatus should mainly be reserved for fracture injuri combined with extensive soft tissue injuries or vascular injuries.

49



49 The equipment: Transfixing, self-drilling bone pins. Couplings and universal ball joints. Plain and adjustable connecting rods.

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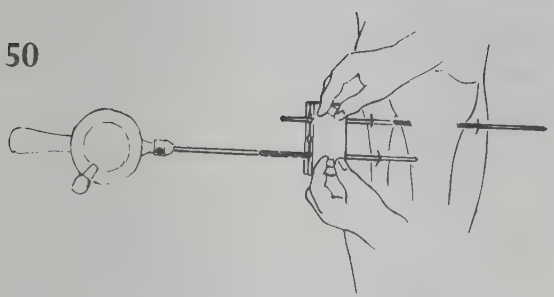

50 The pin insertion: The pins must be inserted only through viable soft tis sues. Drill the pins in series of three. Use the holes in the coupling plate to fin the exact distance between the three pins. The entire procedure may be done under local anesthesia (ill 43 above).

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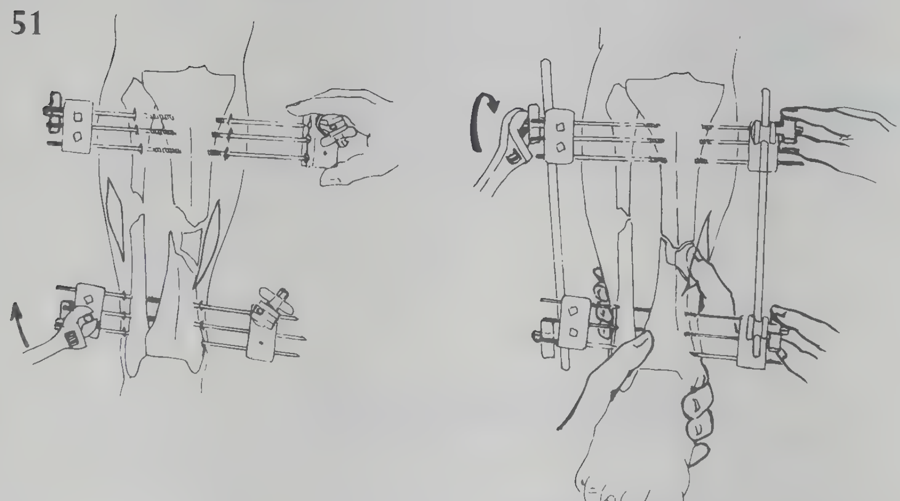
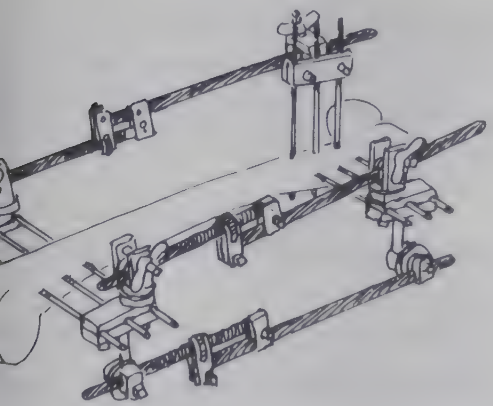


51 Fracture reduction and fixation: Before reducing the fracture, mount the universal ball joints and insert the connecting rods. Then reduce the fracture, maintain the fracture position while your assistant fixes the universal joints tightly. **Notice:** There will always be some bone resorption in the fracture area during the first month after injury. To avoid fragment distraction, adjust the compression stirrup (if any) on the two connection rods – or slightly release the rods, compress the fracture manually, and retighten the universal joints.



52 **Improvise!** Depending upon which bone is fractured, and the location of the soft tissue wound, you may use penetrating pins or half-pins. You may use two, three or four connecting rods.

Traction

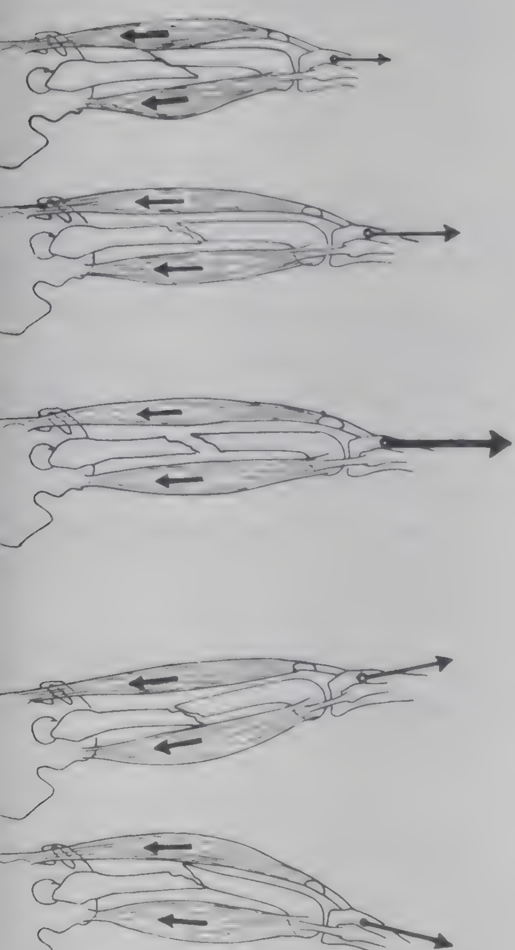
The problem: Traction inactivates the patient; his general condition will soon deteriorate.
Alternative 1: Use traction for only 1–2 weeks until the soft tissue problem (edema, wounds for skin grafting, vascular injury) is managed. Then apply plaster or external fixation and mobilize the patient with active exercises.
Alternative 2 – use dynamic traction (p. 213) where possible
- It does not immobilize the joints proximal and distal to the fractured bone
- It stimulates the blood circulation and soft tissue healing, and thereby accelerates the bone healing
- It stimulates his general condition

Indications for dynamic traction
- All fractures without severe diplacement of the fragments
- All fractures where the bone growth zones (epiphyseal plates) are not displaced

Warning
- Pins and wires inserted through damaged or infected soft tissue may cause bone infection
- Do not apply pin/wire traction on patients younger than 18 years old: Their bone growth centers may be damaged

tion on spinal fractures is not dis ed here. Management of spinal ures – see Chapters 25 and 26.

traction weight for a femoral ure is approximately 10% of the weight. For a pelvic fracture ger mass of muscles) the weights somewhat higher. For an arm ture (less muscle mass) the ghts are less than 10%.



53 **Traction – the principle:** The traction force should be strong enough to counteract the muscular tension working upon the fracture. The traction weights differ depending upon the bone fractured, the age of the patient and his feature. **Notice:** Traction is active therapy! Monitor the traction weight so that it exactly balances the muscle tension. Too light traction weights – the fracture will overlap. Too heavy traction weights – the fracture becomes distracted.

54 **Monitor the direction of the traction:** Angulation of the fracture is corrected by adjusting the axis of the traction, and by pillows under the fracture.

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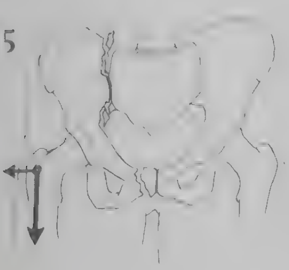

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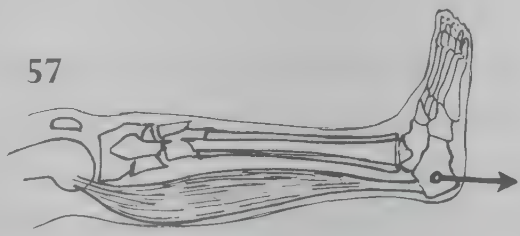
55 Types of fractures fit for traction management – unstable fractur of the pelvic ring: Longitudinal tibia traction with 30 degrees abduction ir the hip joint – or combined traction on the tibia and eye screw trochanter tr tion.

56 Femoral shaft fractures: Dynamic traction upon the tibia. Pin insertio cm below and 2 cm behind the tuber of tibia.

57


57 Fractures of the upper two thirds of the tibia: Traction throu the lower tibia or calcaneus. In calc neus the pin insertion point is sligh above and behind the center of calc neus.

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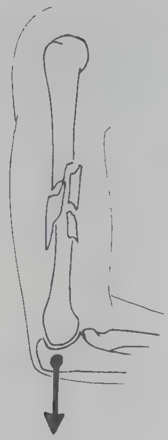

58 Fractures of the shaft and lower third of humerus: Olecranon eye-screw or Kirschner wire traction. The point of insertion is 3 cm distal to the tip of olecranon.

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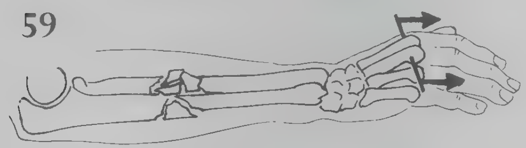
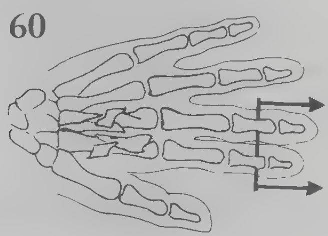


59 Forearm fractures: Traction through the 2nd and 3rd metacarpa bones. Wire insertion 2 cm proxim to the finger joints.

60


60 Multiple metacarpal fractures: Finger traction. Wire insertion 1 cm proximal to the fing joints.

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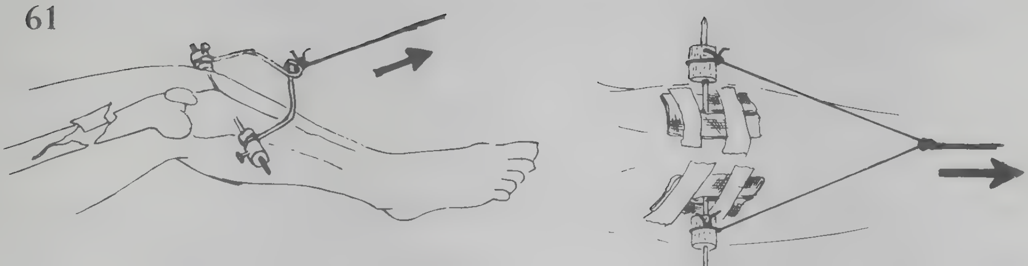
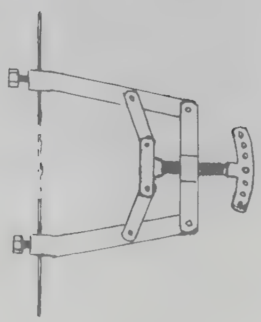
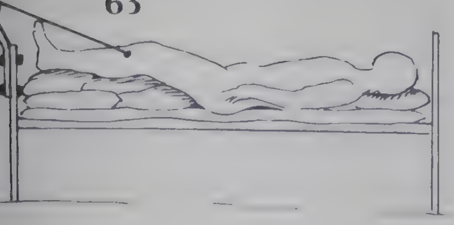


61 The practical procedure: Th Steinmann pin is best fitted for leg traction. Locate the traction point exactly, work sterile, apply local anesthesia and insert the pin (ill 43, 44 above). Split bandage at each pin ning point. The standard Boehler st rup is applied, but improvisations a as effective.

62


62 The Kirschner wires are too thin to support the traction weights – unle they are stretched with this particular instrument.

63



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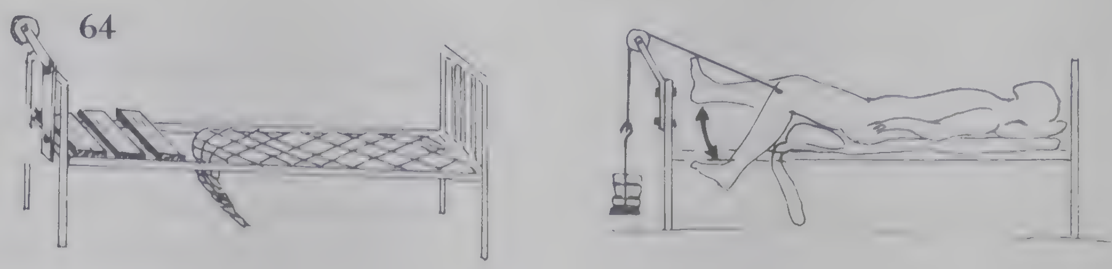
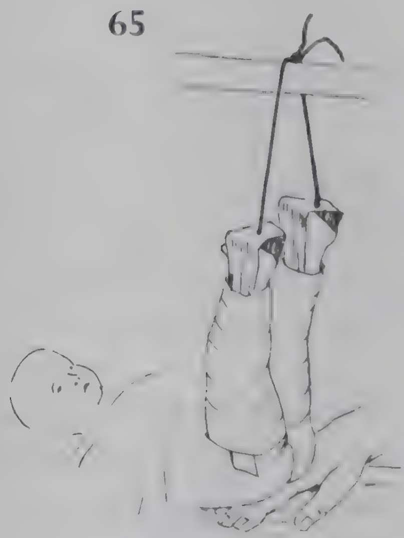


Static traction – the principle: [...]e fractured limb is elevated upon [...]ows. Active ankle and foot exer[...]es are done, but the knee joint is [...]mobilized.

64 Dynamic traction – the principle: Three days after injury exercises should start, 15 minutes in repeated intervals under analgesia. For femur fractures the bed is arranged to allow knee flexion. With an assistant's manual support of the fractured femur, moderate flexion-extension exercises of the knee and hip joint are done. Gradually, as pain recedes, the range of knee and hip motion is increased and so are the training periods.

65



65 Adhesive plaster traction is used in patient younger than 18 years old. Also as temporary traction the plaster traction is useful during surgery, for some days monitoring after vascular surgery etc. Shave the leg. Apply a strong plaster sling exactly along the axis of the limb. Fix the sling with circular turns of crepe bandage. Arrange traction upon a small wooden plate in the end of the plaster sling. Illustrated here is the plaster gallows traction. It is used in femur fracture management in children younger than three years. Even if just one femur is injured both legs are set on traction. The traction weight should be just enough to lift the buttocks of that child slightly from the bed. **Notice:** There is danger of ischemia in the legs of that child. For the first 48 hours the feet must be continually observed for their skin color and temperature. On suspicion, release the circular strapping, or shift to plaster spica treatment.

Monitoring the dynamic-traction patient

The conditions for healing:
- Active exercises of the fractured limb, in particular the first two weeks after injury
- No angulation or distraction of the bone fragments. Monitor the axis and weight of traction daily

Expect callus to develop within four weeks after injury. The signs of callus formation are:
- He can exercise with increasing range of motion without pain
- The fracture is elastic on testing

No clinical signs of callus formation after four weeks – suspect:
- He did not exercise
- Distraction of the fragments – reduce the traction weights. A slight overlap of fragments is not a problem
- Muscle is interposed betweens the fragments – consider surgery
- Fracture infection – consider surgery

When there are signs of callus formation:
- Apply a well-molded long plaster cast (see Chapters 42 and 43), or
- reduce the traction weight stepwise to zero within four weeks under continuous exercises. Then mobilize (on crutches) with careful and increasing weight-bearing. **Notice:** Increasing pain and reduced motion when the traction is reduced indicate lack of callus.

Expect prolonged healing in
- Elderly patients
- Multi-injury patients
- Major soft tissue injury of the fractured limb

Delayed healing and infected fractures

Despite good soft tissue management and effective fixation some fractures do not seem to heal – even after three months there are no signs of bony union on the X-rays. And by clinical testing the fracture remains just "elastic". That is a case of delayed healing. You should consider the reasons why:

- **Missed infection?** A low-grade osteomyelitis may prevent bony union. The common reason for secondary fracture infection is poor soft tissue protection around the fracture. A bone fragment without blood supply may be left after the debridement, being a source of low-grade osteomyelitis. Or there may be an abscess in some deep wound pocket maintaining the infection. The treatment is surgical, and there is no wait-and-see: Explore the fracture, and remove all necrotic bone and dead bone fragments without compromise. Then raise flaps of viable soft tissue to cover the fracture.
- **Vascular injury?** A missed vascular injury proximal to the fracture, may cause delayed healing.
- **Poor nutrition – poor general condition?** Was this patient undernourished, malnourished or did he carry some chronic disease prior to injury? How much weight did he lose? Evaluate his nutrition after injury – was his diet a high-caloric one? Did he spend weeks in static traction, inactivity and mental depression?
- **Rethink your strategy:** In many cases the severely infected fracture is the response to a too optimistic primary evaluation by the surgeon – you tried to save a limb that was not possible to save. The second-hand judgement tells you that primary amputation should have been done. Consider secondary amputation.

Orthosis may accelerate healing

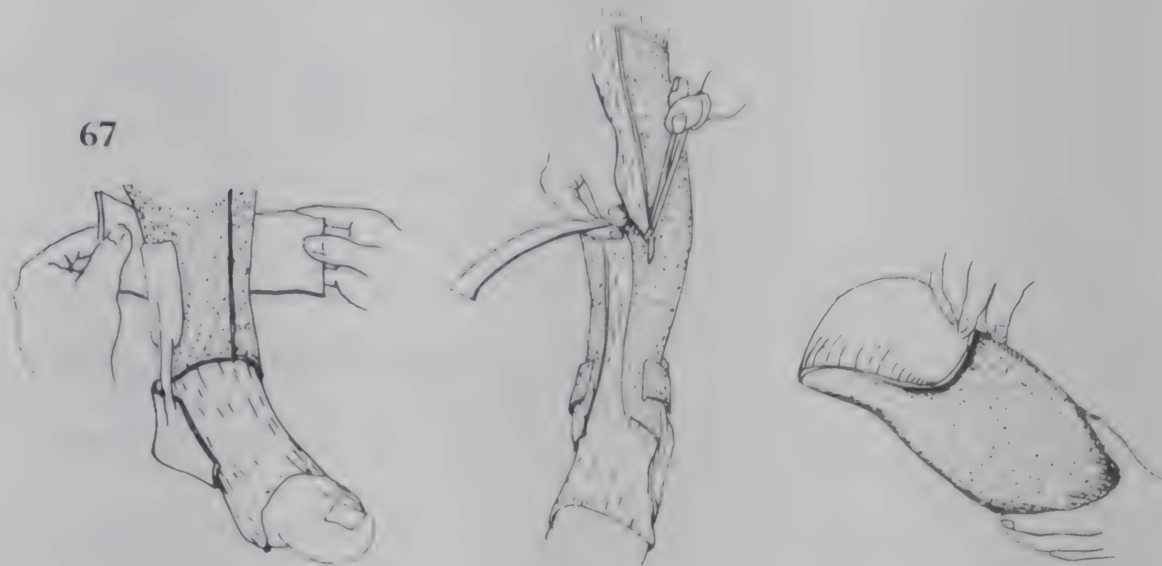
Apply an orthosis if you can exclude infection and the other common causes of delayed healing, or if there is at least some callus. The orthosis is based upon the concept that soft tissue pressure upon the fracture and early weight-bearing

will stimulate the bone-healing process. The orthosis can be made from a variety of soft synthetic light plastic material. The material is of low weight, resistant to water and therefore convenient for the patient during training.

66

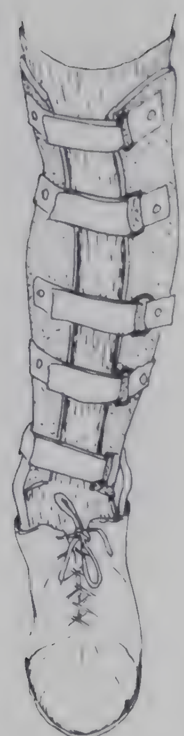
66 How to make an orthosis: The proximal, middle and distal diameters of the limb wearing an elastic stocking are measured. The semi-soft material is cut with a knife and heated at 70-80 degr. C for some minutes. When the material is soft it is applied and molded to fit the limb profile exactly.

67



67 Molding the orthosis: When stiff, the final form is drawn with a pen, the orthosis removed and the edges trimmed. Additional strips are heated for fixation of a heel cast and transverse straps.

68



68 Weight-bearing inside the orthosis is encouraged with a load that is just below the pain limit. The orthosis is removed during bed-rest. Reuse for another patient is possible by heating and remolding the material.

69

69 Plaster cast orthosis: The orthosis principle may be used during the final stage of any kind of long bone fracture management. Two long strips of adhesive plaster fix the orthosis to the leg. Do not pad much; a stockinette elastic bandage is ideal. Apply a standard, snug-fitting circular plaster cast. Bend over the adhesive plaster and fix it inside the cast by some circular turns of plaster. **Notice:** The areas around the tibial condyle and the ankle must be exactly molded to prevent rotational stress upon the fracture when the patient is walking.

Points to note – Chapter 12

Study the anatomy of the main joints
- the shoulder joint: p. 486
- the elbow joint: p. 493
- the hip joint: p. 470
- the knee joint: p. 530

Do not miss an open joint injury
- make diagnostic needle puncture to find out if the joint is hit: p. 223
- fracture lines may enter the joint: p. 221

Close open joint injuries after the debridement
- note different methods to close a joint: p. 220
- know the muscle flaps that may be used for joint closure: p. 200
- note how continuous joint washing is done: p. 220

12 Joint injuries

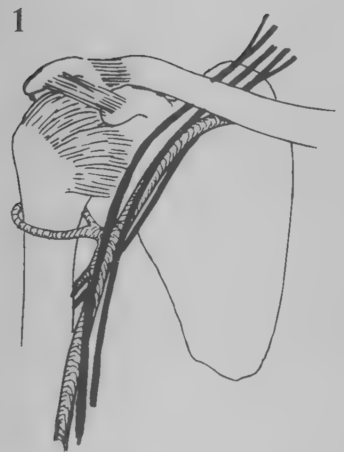
Evaluation of joint function

Joints are structures with an active physiology, and with a high capacity for healing and protection against infection. **Synovium** is the thin mucosal membrane lining the joint surface of the capsule. Synovium produces and resorbs the synovial fluid.
The joint bony surfaces are lined with cartilage. The cartilage has no blood vessel nutrition, its only nutrition being from the synovial fluid. The joint capsule outside the synovium consists of several layers of non-elastic fibrous tissue. Ligaments and tendons are interwoven with the capsule to form a functional unity – **the capsule apparatus.**

Synovium is "the joint healer". Any war surgeon who hopes for successful treatment of joint injuries should utilize its healing capacity:

- **Close open-joint injuries during primary surgery:** Synovium produces the synovial fluid. This fluid contains nutrition for the cartilage. It also contains chemically active components protecting the joint against infections. "A dry joint is a dead joint": Without synovial fluid the joint will undergo cartilaginous necrosis and general infection within a few days. Cover defects in the capsule by some sort of soft tissue flap. Synovium will do the rest by ingrowth gradually lining the inner surface of that flap.
- **Do not excise synovium:** Synovium itself has a rich vascular supply and high capacity for regeneration. During debridement there is no need to excise synovium.
- **Synovium needs nutrition:** Take special care of the soft tissues around the joint during debridement. Stimulate the blood circulation around the joint by early active exercises of the muscular apparatus.

1



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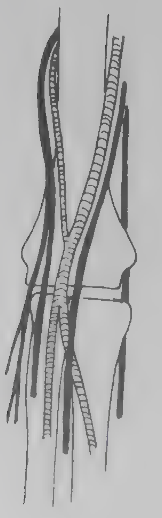


3

The evaluation of extensive joint injuries

Evaluation is difficult. The general guidelines are as follows: Do not try to save a joint if you risk the limb. Do not try to save a limb if you thereby risk the life of that patient. Several factors must be evaluated:

- **Associated injuries?** In serious cases, the primary concern is life saving. Every other treatment is secondary to that. If early mobilization is vital, do not tie the patient in bed for a devastating immobilization just to save a joint.

1 • **Injury to nerves and vessels?** Main nerves and vessels run close to the joints – here the axillary vessels and the nerves for the arm at the shoulder joint. In most extensive joint injuries with associated nerve and vascular damage the best result will be a painful and useless limb. Better perform primary amputation.

2 **The elbow joint:** Suspect associated injury to the radial artery, the radial, median and ulnar nerves.

3 **The knee joint:** Associated injury to the popliteal artery (prolapse of intima), the sciatic and peroneal nerves is common.

- **A weight-bearing joint or not?** The load upon the shoulder joint is far less than that of the ankle load. In a weight-bearing joint the cartilaginous surface cannot be decreased by more than 30% without causing instability and chronic pain. For displaced intra-articular fractures the treatment of choice may be arthrodesis (ill 13) or amputation. A non-weight-bearing joint may be treated with excision of the fractured bone end (ill 12).
- **Extensive capsular and ligamentous injury?** In a weight-bearing joint stability is essential to function. An unstable joint will cause chronic pain. If the patient after a successful primary treatment still needs elaborate reconstructive surgery to stabilize the joint, a primary arthrodesis may be the treatment of choice. A non-weight-bearing joint has far less demands for stability and should be reconstructed.
- **Joint injury in children:** Children have a healing capacity far better than adults. As a general rule you should always try to save a child's joint.

Battlefield management of penetrating joint injuries

- Wash the joint with large amounts of NS through the inlet and outlet wounds.
- Instill soap solution into the joint and leave it there during the evacuation.
- Insert a large-bore tube drain into the joint.
- Wrap the joint in crepe bandage and immobilize it on a long splint.

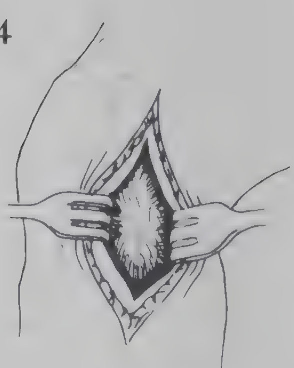
Two-step surgery

If the limb can survive and you are in doubt whether to reconstruct the joint or not, you can safely delay your decision: Concentrate on vascular repair and a proper soft tissue debridement. Re-explore the joint after 4-5 days – and then decide your management strategy for that joint.

The soft tissue problem

Like the peritoneum of the abdomen, synovium will swell and seal a minor penetrating wound. Thus you cannot decide just by exploring the inlet wound whether a small missile has entered the joint or not. Diagnostic joint aspiration: ill 14 - ill 19. If you have the slightest suspicion of a penetrating joint injury, the synovium must be opened and the joint fully explored.

4

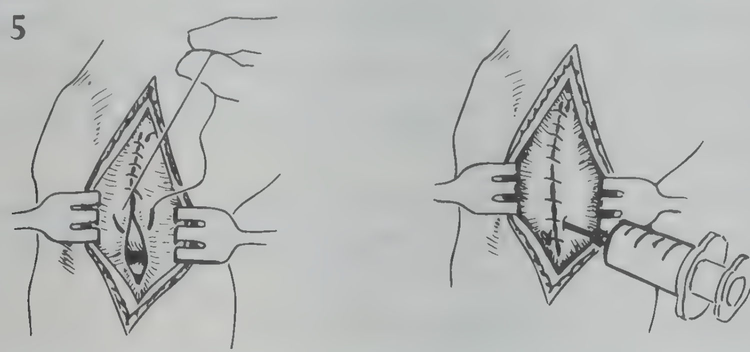


4 **The exploration in principle (the knee joint):** The skin and the fibrous capsule are incised longitudinally along the fibers until you see the reddish synovium bulge through the capsular incision. Synovium is grasped and incised between forceps, the synovial incision extended and the joint explored between long blunt retractors. **Wash the joint:** All dirt and loose bodies must be washed out. A hematoma inside the joint may be a focus for joint infection and should be washed out. Also the blood may organize and form adhesions inside

Standard exploratory incisions:
- shoulder: p. 487
- elbow: p. 495
- wrist: p. 504
- hip: p. 474
- knee: p. 533

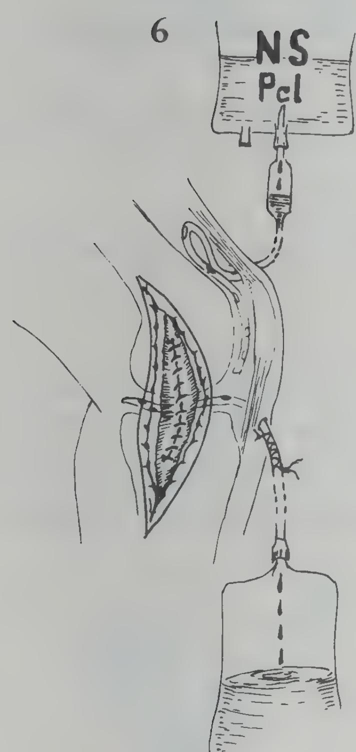
the joint which may restrict the joint movement. To reach all compartments and pockets inside the joint, wash through a thin soft plastic tube with large amounts of normal saline. In dirty joint injuries and infected cases: Instill a dilute soap solution in the joint for some minutes – then wash it all out with normal saline. **Notice:** Be careful with the soft tissues around the fracture; better use double or triple longitudinal incisions to handle the fragments rather than extensive dissection and rough traction through one incision.

5



5 Standard closure of joints: Close synovium tightly with a continuous over-and-over suture. Instill penicillin (5-10 mega IU) in normal saline (40 ml for a knee joint) into the joint, and close the fibrous capsule with interrupted strong sutures. Leave the skin incision open for delayed suture.

6

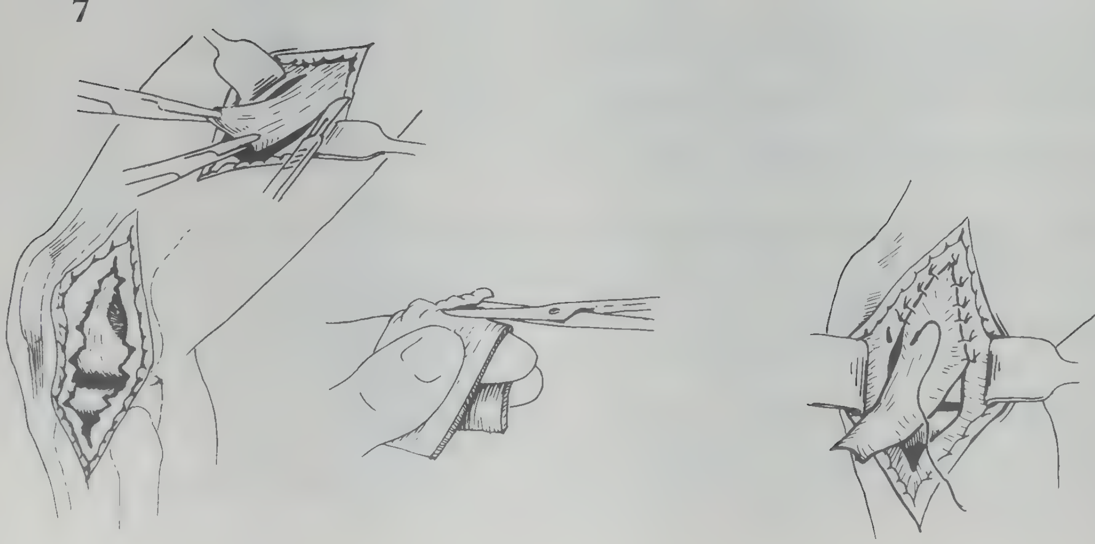


6 Continuous joint washing in high-risk injuries: In open-joint injuries with extensive tissue damage, injuries more than eight hours old or joints containing dirt and debris – arrange a continuous antibiotic washing of the joint for 1-3 days. Cut the tube of an i.v. infusion set, cut some side holes in it, and put it through a separate stab incision into the joint before closing synovium. For dependent drainage, a urinary catheter (small caliber) with side holes is put into the distal part of the joint through another separate low incision. Then close synovium tightly. Small leaks will close spontaneously. Let the washing run slowly, 5 mega IU penicillin to each liter NS.

Wide open joints – what to do?

It is imperative to close the missile track and exploratory incisions at the time of primary surgery. But the joint capsule is non-elastic, and even a minor capsular deficit after the debridement can make it impossible to close the wound by simple suture. Mobilize a local soft tissue flap (full thickness skin flap or skin-muscle flap) and rotate it to cover the capsular defect (ill p. 534). The objective is to achieve a seal good enough to permit synovial fluid to collect inside the joint. Within days the flap will be lined on the inside by ingrowth of synovium and leaking stops spontaneously.

7



7 Fascia grafts for closure: Instead of skin/muscle flaps a broad-based full thickness fascia flap can be raised and rotated onto the capsular wound. Or you may use a free fascia graft as illustrated: A graft of appropriate size is taken from the femoral muscle fascia (fascia lata). Clean the graft of fat and muscle attached to it. Close the capsule defect by that graft. **Notice:** A free fascia graft is a temporary measure to close the joint during

Skin flaps: p. 255
Muscle flaps: p. 200

primary surgery. Within some days the free graft will turn necrotic and has to be removed. At that time the condition of the patient should be stable, and a proper joint reconstruction and soft tissue flap closure can be done.

If the injury is so extensive that you are not able to close the actual joint by the flap method, then partial joint resection, primary arthrodesis or primary amputation should be considered.

Fracture through joints

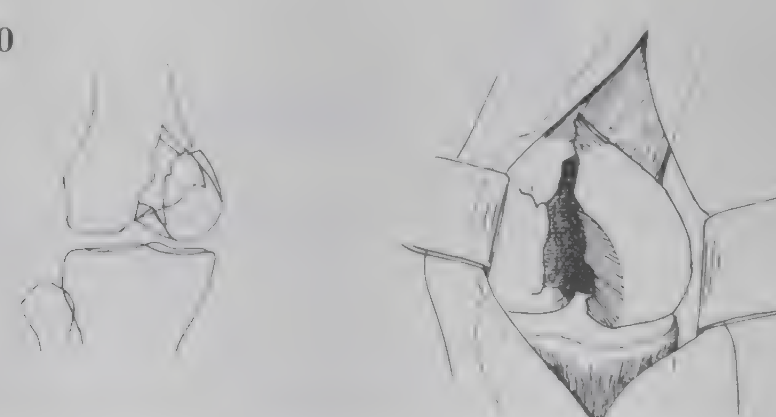
8

9

8 Does an open fracture enter the joint? If so, there is in fact an open-joint injury, and the joint may become infected through paths in the fracture field indicated by black arrows. Early diagnosis is essential: Study the anatomy of each joint, in particular the compartments and extensions of the main joints. Eg. the superior compartment of the knee joint extends more than 5 cm above the top of the patella. Thus fractures and deep soft tissue wound of the lower third of the thigh may well enter the joint. In all penetrating injuries close to major joints: Do diagnostic needle aspiration of the joint (ill 14 - ill 19) – aspiration of blood indicates open-joint injury: That joint has to be explored during surgery. **Notice:** By X-ray examination minor fracture lines that enter the joint may not be seen. Still they are big enough to act as an entry for bacteria. Also injuries of the cartilage cannot be seen in X-rays.

9 Fractures of the cartilage: Free fragments of the cartilage are removed. Wash the joint thoroughly in order to find all free fragments; otherwise they become "loose bodies" that obstruct joint movement. Trim the edges of ragged cartilaginous wounds with a knife.

10



10 Intra-articular fracture fragments – are they rotated? Minor bone fragments may be excised if they are not located in the central weight-bearing part of the joint surface. The actual fragment displacement may be difficult to assess from the X-rays. Explore the joint and align the fragments. See to it that no soft tissue is interposed between the fragments (ill 11). Arrange dynamic traction or plaster cast immobilization (p. 213).

11

Primary bone grafting into open missile fractures carries a high risk of fracture infection. Bone grafting should be delayed until the soft tissues have healed without infection.

11 Comminuted intra-articular fractures: Steps more than 3-4 mm between fragments of the joint surface should not be tolerated. The fracture here illustrated must therefore be explored and reduced. Apply traction (manual, plaster or pin traction) before you start surgery. In particular look for soft tissue interposition – maybe some torn muscle is crammed inside the fracture and prevents reduction of the fragments. In very compound fractures with multiple small fragments exact surgical reduction is impossible: Remove minor fragments and soft tissue interposition; close the joint and arrange dynamic traction. Order effective analgesia and start active and passive exercises with careful movements of the joint in an intermediate position from the first day after surgery. The joint motion will "model" the joint ends and further reduce the fracture.

12

13

12 Destroyed joints – consider primary resection: Resect all free bone fragments. Mobilize a capsule/muscle flap into the joint space as "padding". After 6-8 weeks immobilization in a plaster cast, weight-bearing is started. The end result will be a joint with fair movement but poor load resistance.

13 Destroyed joints – consider primary arthrodesis: Resect the bone ends to get good contact of raw bone surface with the joint in functional position. Immobilize for 3-4 months in plaster cast, cast with pinning, or external fixation apparatus. The end result will be a stiff, but painless "joint".

Infected joints

A joint may become infected through the bloodstream from some other local infections. Multi-injured and cases in poor general condition carry a particular risk of this complication. More often infectious arthritis is a result of poor primary management: Tiny high-velocity missile injuries are missed, fracture lines that enter the joint are not diagnosed – or the debridement was insufficient.

The signs of joint infection:
- Increasing pain on joint movement. Gradually the joint is left in a contracted position and the patient will not let you move it.
- Swelling of the joint.

- The local tissues are reddish and warm.
- Fever and poor general condition.

On the slightest suspicion: Perform diagnostic aspiration of the joint!

To treat a joint infection
- Open that joint immediately and explore for missed injury. In particular look for bone fragments without blood supply and abscess formation in some deep wound pocket next to the joint.
- Wash the joint with dilute soap solution and amounts of NS.
- Arrange continuous washing with antibiotics.
- Drain the soft tissues next to the joint well.
- Total immobilization of the infected joint.
- I.v. antibiotics.

14

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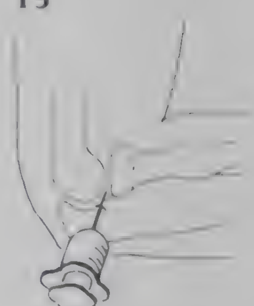

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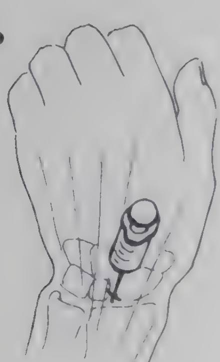

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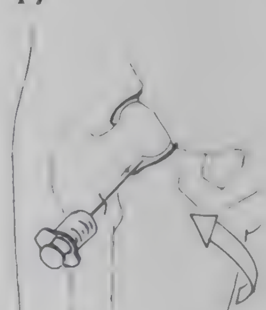

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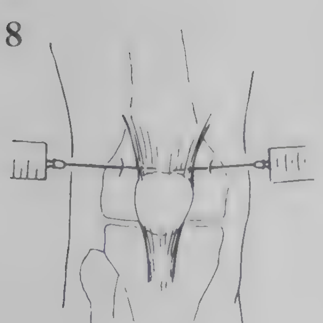

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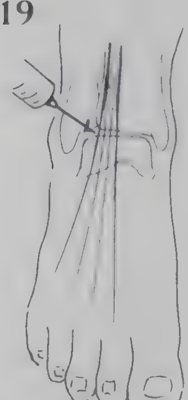


14 Joint aspiration – the shoulder joint: Work sterile! Use a large-bore needle and infiltrate local anesthetic on your route towards the joint. The normal synovial fluid is yellow, smooth and clear. In joint infection the fluid becomes thick and cloudy with debris. The shoulder joint: Rotate the arm outwards. Direct the needle towards the lower part of the joint. Here the joint space is wider.

15 The elbow joint: Flex the joint. From the lateral side you can identify the head of radius. Direct the needle just proximal to the head of radius into the joint.

16 The wrist joint: The inlet point is just radial to the index extensor tendon. The needle is directed – not 90 degrees – but 60 degrees to the skin, and in the proximal direction.

17 The hip joint: Use a long (spinal) needle. Rotate the femur outwards. The inlet point is in front of (not medial to) the femur, at a level of the lower part of trochanter. Forward the needle until you feel the base of the neck of the femur on the needle point; then "walk" the needle along the neck of the femur, step-by-step switching the direction of the needle towards the medial and lower part of the joint.

18 The knee joint: The inlet point (on either the lateral or the medial side) is 1 cm proximal and 1 posterior to the upper corner of the patella. From here, forward the needle in a horizontal direction.

19 The ankle joint: Palpate the space between fibula and tibia. The inlet point is just lateral to the toe extensor tendons.

Points to note – Chapter 13

Do not repair tendons at the time of injury
- concentrate on the soft tissues around the tendon injury: p. 227
- note how local soft tissue flaps can be used to cover tendons: p. 255
- study the suture technique for tendons: p. 228

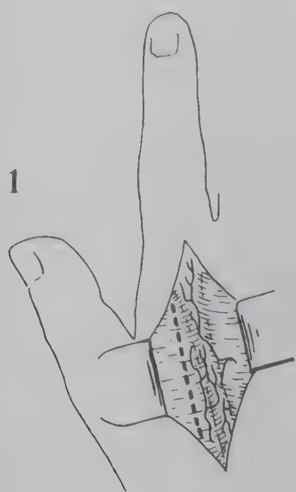
Hand flexor tendon injuries are different: p. 228 and 501

13 Tendon injuries

Primary management

The tendons have great capacity to heal after injury – on two conditions:
- That the tendon blood supply and nutrition remain undamaged
- That the tendons are covered by viable soft tissue.

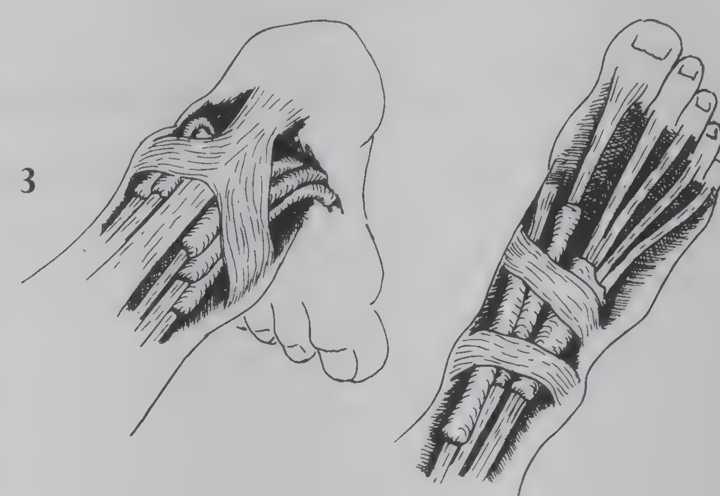
1



1 The tendon blood supply: All tendons are covered by a thin sheet of loose connective tissue. In this sheet runs a fine network of blood vessels that enter the tendon. Close this sheet when the debridement is done – exposed to air tendons cannot heal.

2

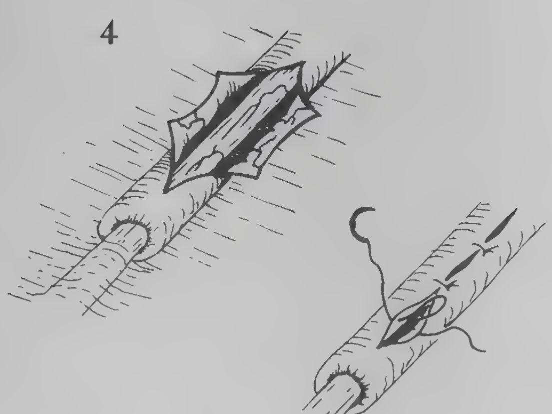
3



2 The tendon synovium: In some areas the tendons are protected by a specialized synovium – here the hand flexor and extensor synovium.

3 The flexor and extensor synovium of the foot.

4



4 The tendon synovium contains a clear yellow viscid fluid that lubricates and provides nutrition for the tendon. Inside the synovium is a delicate network of blood vessels. For protection and nutrition the synovium should always be closed after exploration and debridements.

The general procedure for tendon injuries: Two-step surgery

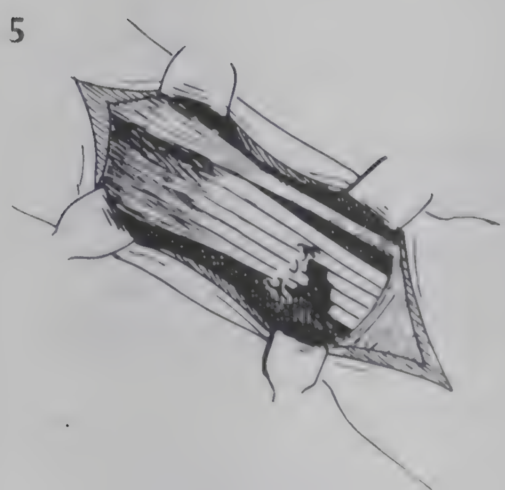
Before surgery

- Nerve function tests (p. 120) may indicate tendon injury as the main limb nerves run close to the tendons.
- Associated vascular injury? Both vascular and nerve injury has priority over tendon injuries.
- Assess the degree of soft tissue injury. Plan the skin or muscle-skin flaps you intend to use to cover the injured tendons (p. 255).

The primary management
- Explore the wound, identify and examine each injured tendon carefully.
- Concentrate on good debridement of the soft tissues around the tendons.
- Mobilize and adapt viable soft tissue flap cover over the tendons. Leave the rest of the wound open.
- Report the tendon injury very accurately in the Injury Chart, or make a drawing.

The secondary reconstruction
- Re-explore the injury when the soft tissues are cleared of infection and the skin has healed completely (3-6 weeks after the time of injury).
- Reconstruct the tendons.

5

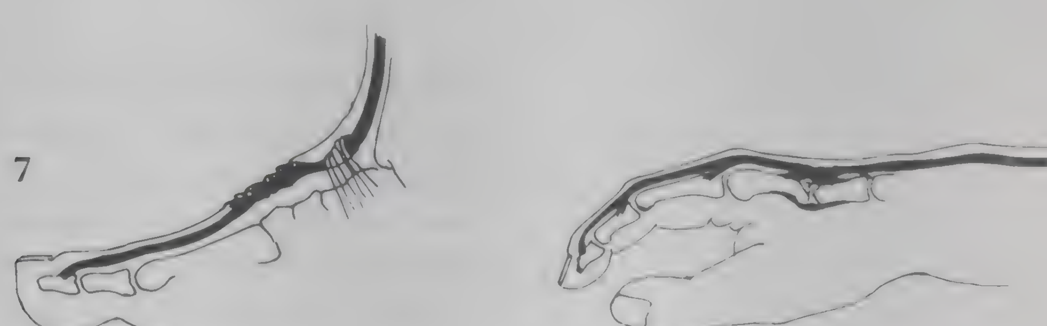


5 The exploration: Due to muscle tension, the tendon ends retract, especially the proximal ends of the flexor tendons will retract considerably after injury. Extend the wound into a wide exploratory incision. Dissect the soft tissues carefully and identify the injured tendons one by one. **Notice:** Are you sure what you identify as a "tendon" is not a nerve (p. 234)? Pull the proximal ends of the tendons towards the level of injury, debride only the most ragged parts of the tendons, and fix them with some suture to the soft tissues to prevent retraction. (A thin steel suture is convenient for later X-ray identification.)

6

6 Cover and drain the tendons: Wet the tendons with normal saline every five minutes during surgery. Mobilize viable soft tissues from the side of the wound, and anchor them with interrupted sutures over the tendons. Drain well through separate stab incisions. If there is major soft tissue deficit, design a local full thickness skin or muscle-skin flap, and rotate it onto the wound to cover the tendons. If you cannot cover the tendons with local flaps, make normal saline-wet dressings for some days: That will promote a bed of granulations for secondary split-skin grafts.

7



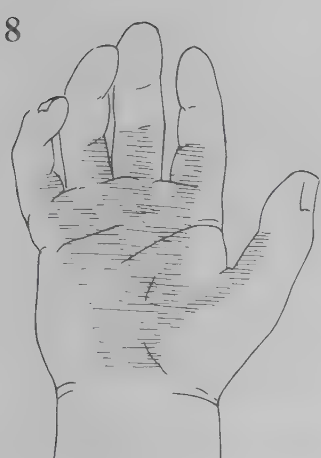
7 Free tendon movement: Excessive scarring will destroy tendon function as the tendons become attached inside the scar tissue. The tendons may also become trapped in the callus of an underlying fracture. Do not let a wound over a tendon heal by spontaneous granulation. Do not apply free skin grafts directly onto tendons. Start active and passive exercises (analgesia!) from the first days after primary surgery to prevent tendon attachment and contractures.

Secondary reconstruction

Reconstruction should be undertaken as soon as possible after the injury. But four conditions should be fulfilled:

- The skin is healed.
- There is no local infection.
- There are no contractures in the distal joints up on which the tendons shall work.
- There is no extensive scarring in the field. Any reconstruction inside a scar-filled wound is useless: The scar will invade the tendons and prevent their free movement.

8

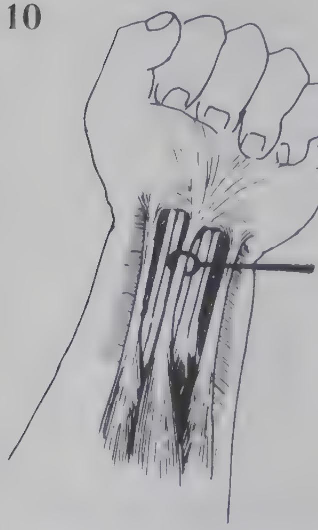


8 "No man's land": Reconstruction of hand flexor tendons inside their synovial sheath is difficult even in experienced hands. Tendon injuries inside this shaded area should be exactly debrided as soon as possible after injury. Concentrate on proper soft tissue cover (flaps in hand surgery, p. 256 and 507). Refer the case to an experienced surgeon for reconstruction as soon as the soft tissues have healed without infection.

9

9 Tendon suture: Mobilize the proximal and distal ends of the tendon, free them from scar tissue and adhesions. Atraumatic technique not to damage the tendon blood supply! Apply double mattress sutures. You may add some interrupted sutures for approximation. Silk 3-0 to 5-0 is convenient. Cover the anastomosis with viable soft tissues. Immobilize for two weeks in a position where the anastomosis is not under tension. After two weeks start exercises within a narrow range of motion.

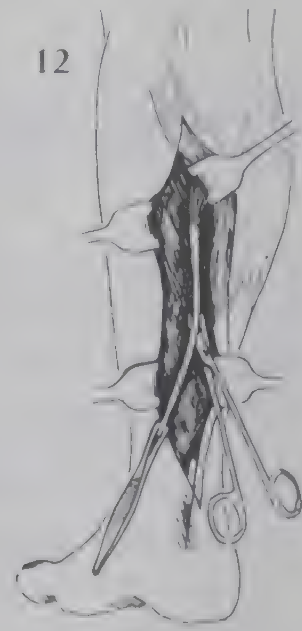
10



10 Tendon graft – the palmaris tendon: Never suture tendons under tension, the anastomosis will give in. If there is loss of tendon tissue due to injury and debridement, better interpose a small tendon graft. The palmaris tendon can be removed from the wrist with no loss of function.

11

12



11 Tendon graft – one of the index extensors: There are two extensor tendons to the index finger. You may excise one of them without loss of function.

12 Tendon graft – the plantaris tendon: The plantaris tendon makes a long graft. You find it on the medial side of the Achilles tendon.

13

13 Graft reconstruction: The grafts are trimmed and sutured without tension. Notice the needle inserted during surgery to prevent retraction of the proximal tendon stumps. Immobilize for two weeks before intensive exercises start.

Points to note – Chapter 14

Know the exact anatomy of the main limb nerves. As the limb nerves follow the arteries, identification of nerve injuries may be the key to diagnosis of artery injuries: p. 120.

- the brachial plexus: p. 303
- the nerves in the arm: p. 487
- the nerves at the elbow: p. 493
- the nerves in the forearm: p. 499
- the nerves in the hand: p. 503
- the nerves at the groin: p. 678
- the sciatic nerve: p. 518
- the nerves at the knee joint: p. 531

Do not miss nerve injuries

- know how to test the main limb nerves for injury: p. 120

Nerve injuries are not repaired at the time of injury

- but find out if the injury is partial or total: p. 232
- note how local soft tissue flaps can be raised to cover injured nerves: p. 255

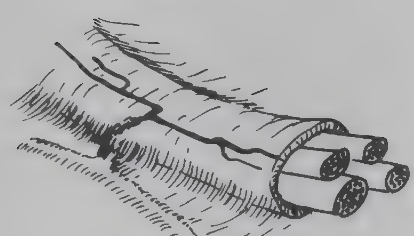
14 Nerve injuries

Diagnosis and exploration

The general procedure

- **First – clinical and neurological examination:** Study each inlet/outlet wound; imagine the internal wound track and consider if any main nerve may be hit. The neurological examination is part of the triage: Make a rapid examination of the motor and sensory function of each main nerve. It is too late to examine the nerve function when anesthesia is given.
- **Surgical exploration?** Any dysfunction of a main nerve indicates surgical exploration at the time of primary surgery. You cannot estimate the degree of nerve injury from the clinical examination alone.
- **Secondary nerve reconstruction:** Never suture damaged nerves during primary surgery. Reconstruction is done when the soft tissues have healed without infection.

1



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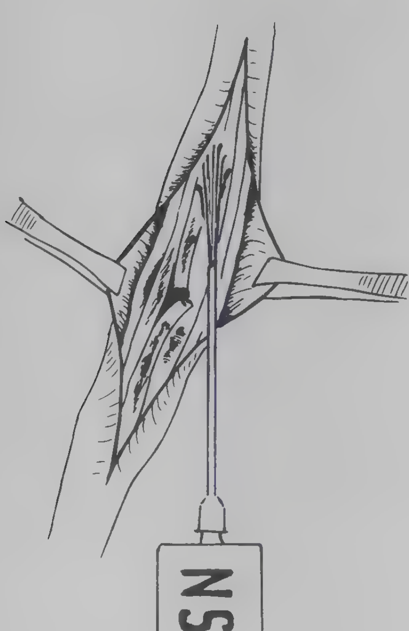

1 **The nerve anatomy:** The nerves are protected by a sheath of loose connective tissue – the epineurium. Inside this sheath runs the vascular supply to the nerve. The nerves are composed of both sensory and motor fascicles.

2 **Partial or total injury?** Nerve injuries are seldom caused by a direct missile hit. Most often you find the nerve ruptures close to comminuted fractures where the nerves are hit by "bone missiles" or trapped in the fracture. Eg. damage to the radial nerve is common in mid-shaft fractures of the humerus. Most often the nerve is continuous but swollen/discolored on inspection: Split the nerve sheath to assess the actual degree of fascicle damage. Take care not to injure the fine blood vessels supplying the nerve. Fascicles obviously torn or crushed are trimmed, but leave partially damaged fascicles alone: Manipulation may increase the scar formation and complicate a later reconstruction. **Notice:** Mark the level of injury with a small steel suture close to the nerve. Report exactly in the Injury Chart the degree and level of injury.

Neuropraxia

In high-energy missile injuries the nerves are often stretched or squeezed by the shock wave without the fascicles being broken. The result is the neuropraxia – a state of nerve irritation with some nervous dysfunction which heals spontaneously in most cases. Neuropraxia is the most common wartime nerve injury.

Soft tissue protection!

As for the tendons, the nerve will soon become necrotic and infected if it dries in the air without soft tissue cover. Keep the nerve wet with NS during surgery. Concentrate on proper debridement of the soft tissues surrounding the nerve. Wash the nerve with antibiotics in normal saline. Then close the nerve sheath with interrupted sutures. If you are not able to adapt the debrided soft tissues as a cover of the nerve, mobilize a soft tissue rotation flap (p. 255).

Drain well; secondary hematomas may cause infection and excessive scarring. Immobilize the site of injury for two weeks, but order active exercises of the distal motor units controlled by the injured nerve.

3

3 Tinel's sign for nerve regeneration: The nerve fascicles regenerate from the level of injury in the distal direction. The growth is slow, maximum 1 mm per day. You may test the level of regeneration with "Tinel's sign": Tap your finger distal to the site of injury. If the response is distal-radiating sensation along the nerve, some regeneration of the nerve fascicles is under way.

Prepare the reconstruction

- **Information:** You need active participation from the patient, explain him why, how and when.
- **Order active exercises:** Most nerve injuries are not total – active exercises help maintain the function of the nerve fascicles not injured.
- **Order passive exercises:** Why reconstruct the nerve if his joints turn stiff? Maintain joint and tendon function by passive exercises.

Secondary nerve repair

Warnings

- As important as performing skilled reconstructions is to select the patients for whom reconstruction is not possible. Extensive nerve injuries are difficult to reconstruct, even for the experienced surgeon. The reconstruction may in fact cause increased dysfunction and pain. For some patients amputation and a painless prosthesis is the treatment of choice.
- There must be no local infection.
- Secondary nerve repair in a scar field will fail: The nerve anastomosis will be invaded by scar tissue.
- Children have great capacity for nerve regeneration: Do not rush with the secondary surgery.
- Even in the most experienced hands, the results of nerve reconstruction in total ruptures are poor; the result may even be worse than before reconstruction. Refer your cases to experienced surgeons if you can.

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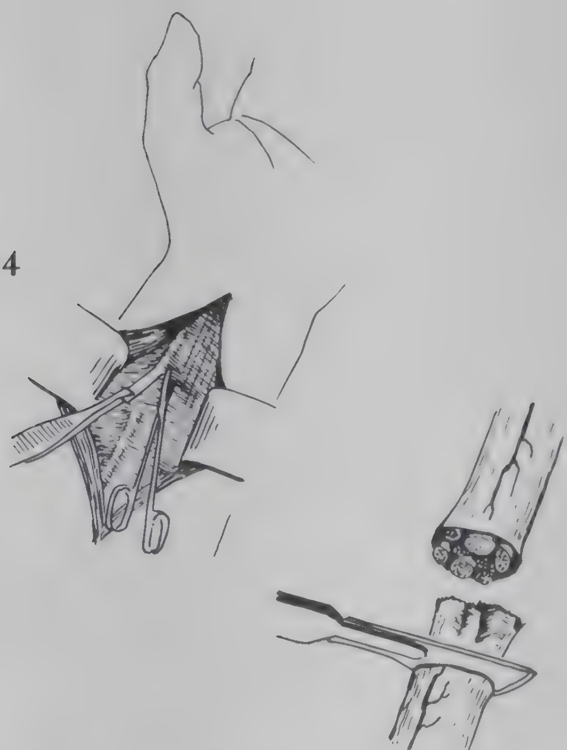

4 Secondary nerve repair – the procedure: The proximal and distal nerve ends are packed in fibrous tissue. Identify the nerve ends by careful dissection. Make trial sections of the nerve ends until you identify nerve fascicles without scarring.

Points to note – Chapter 15

Find out when primary amputation must be done
- amputation may be life saving in multi-injury cases: p. 239 and 160
- assess the total function of the injured limb – the forearm and hand: p. 499. The lower leg and foot: p. 538
- disarticulation to free trapped persons: p. 241

Manage the amputation stump as any other war wound
- let flap amputations be the main method: p. 241
- do fasciotomies proximal to the amputation level, especially so in mine amputations: p. 85. And in lower leg amputations: p. 539
- leave the amputation wound open. Note how the Trueta plaster method can be used both to drain the stump, prevent stump edema, and to fix a training prosthesis: p. 182 and 242

Note the minimum length of the common amputation stumps
- the forearm stump: p. 499
- the femur stump: p. 528
- the below knee stump: p. 537

Hand and finger amputations are a special problem: p. 509

Design a stump that can bear weight
- note how myoplasty is done: p. 242
- to fit a prosthesis, the muscle bellies should be trimmed: p. 548
- suture the skin and fascia flaps in one: p. 243
- study the pain problem and the psychological reactions after amputations: p. 243
- nerve blocks may reduce the post-operative stump pain: p. 243

15 Amputations

Evaluation of extensive limb injuries

Amputation surgery has come into discredit because it is often conducted in an improper way: First – amputations are performed as the "last resort", when they are too late, and often due to infection or vascular complications. In this way the amputations become complicated with infections and protracted healing. Often unnecessary limb length is lost. Second – amputated patients are not rehabilitated with early exercises and training. The prosthesis service is not taken care of and integrated in the plan of management. Many patients who might have led a proper and active life with some simple prosthesis end up as beggars on crutches among the urban poor. We are confident that this negative concept of amputations will be changed if surgeons were to **study the essentials of modern wartime amputation surgery:**

- **Life before limb:** In serious multi-injury cases, elaborate limb-saving surgery may be a risk to life. The surgeon must have the guts to decide on primary amputation when indicated.
- **Forward amputations may save limb length:** Prompt and skilled emergency amputation as soon as possible after the time of injury may save both life and limb length. If you delay the decision whether to amputate or not, the general condition will deteriorate, the area of muscular necrosis will extend, the risk of complication and reoperations will increase. Limb length will be lost and rehabilitation protracted.
- **Debridement – fasciotomy – drainage:** Treat the amputation stump as any other major wound. Explore every muscle belly carefully, and amputate it precisely above the necrotic area. Apply wide fasciotomies proximal to the amputation level to improve circulation. Drain all spaces and compartments of the amputation stump.

The particular features of mine amputations: p. 85

- **Take immediate care of the nutrition:** As for any other major war wound, high-energy nutrition is essential to rapid healing and early mobilization. In cases late for surgery and soldiers exhausted after days and weeks of fighting, high-energy nutrition should be started before evacuation to second line clinics.
- **Psychological mobilization:** Good results depend on active participation from the patient. Inform the patient of your management plan, that he will be out of bed wearing his first prosthesis within two weeks after the amputation – provided he cooperates actively.
- **Immediate post-operative prosthesis fitting (IPOPF):** Early prosthesis training will accelerate rehabilitation and encourage the patient. Let the patient take active part in planning and producing his prosthesis.

Reasons to do primary amputation

Which limb can be salvaged, and which limb should be amputated after injury? There is no simple answer to this question, many factors influence the healing capacity after severe injuries. But some factors are more important than others:

Table 1

Factors influencing lower limb salvage after injury	**Points**
1 The degree of tissue damage	
Low energy (minor soft tissue damage, simple fractures)	1
Medium energy (moderate soft tissue damage, multiple simple fractures)	2
High energy (close-range gunshot wounds, crush injuries, compound fractures)	3
Very high energy (also avulsion of soft tissue and heavy contamination)	4
2 The degree of circulatory shock	
Systolic BP 90 mm Hg or more all the time	1
Systolic BP less than 90 mm Hg in periods	2
Systolic BP less than 90 mm Hg all the time	3
3 Patient's age (years)	
Less than 30	0
30-50	1
More than 50	2
4 The degree of limb ischemia	
Pulse reduced, but capillary circulation normal	1
Pulseless limb with diminished capillary refill	2
Cool limb with neurological signs	3
5 The duration of limb ischemia	
If the limb has been ischemic for more than six hours, the ischemia scores 4 are doubled	
Sum the points to predict the chance of limb salvage	

Arms and legs are different! An arm with permanent nerve injury and partial loss of skin sensation may well be useful, a leg is not. An arm with bone loss and/or contracted joints may well be useful, a leg of that kind cannot bear weight – and is useless.

Mass casualties are different! Attempts to salvage seriously damaged limbs are time and staff consuming; the clinic capacity will influence the reasons to do primary amputation.

A score of 7 points or more on Table 1 normally indicates that primary amputation should be done; despite the best surgery and post-operative care that limb will probably be lost, or at best end up useless, prosthetic, and with chronic pain. The damaged limbs you try to save should definitely have a score of less than 7 points on this scale. **Notice, Table 1 should be used with care:**

- It is useful only in cases where the limb injury is the main injury; in unstable multi-injury patients you must decide which injury represents the main risk, an injured limb with scores less than 7 may have to be amputated to save life.
- Several factors that influence the outcome are not included in Table 1– such as malnutrition, chronic diseases, and the patient's mental state and motivation.

Types of emergency amputations

The equipment needed:

- General surgical set (small)
- Any saw or a good chisel
- A tourniquet (BP-cuff) proximal on the limb in case of excessive bleeding

Shoulder and forearm amputations: p. 492
Elbow and forearm amputations: p. 508
Hand and finger amputations: p. 509
Hip joint disarticulation: p. 475
Thigh amputations: p. 528 and 537
Knee joint disarticulation: p. 241
Lower leg amputations: p. 548
Ankle and foot amputations: p. 549 and 550

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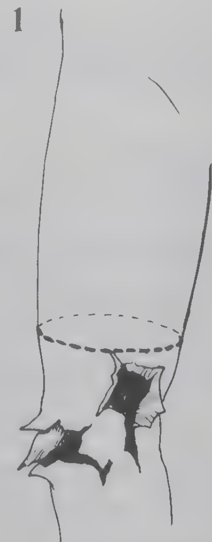

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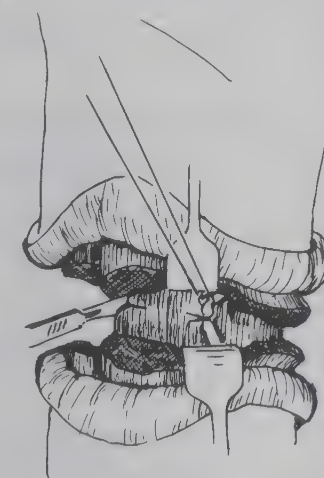

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1, 2, 3 Method one – guillotine amputation: The guillotine amputation is not the standard method of wartime amputations. Indications for this method are patients trapped in destroyed buildings, under vehicles etc. And situations where the amputation must be hurried (serious multiple-injury patients, military emergencies). Circular skin and fascia incision at the most distal level possible. Incise the muscles at the same level and let them retract. Identify the main arteries and veins and ligate them, major vessels with double ligature. Pull the main nerves and cut them at the highest possible level; let them retract into the soft tissues and inject 5-10 ml local anesthetic as nerve block along the nerve trunks. **Notice:** If one muscle belly is necrotic at the level of amputation, make an exploratory longitudinal incision and amputate this muscle at a more proximal level. Leave this incision open as a fasciotomy. If the actual injury was a high-energy one, perform fasciotomies of all the main compartments proximal to the amputation level.

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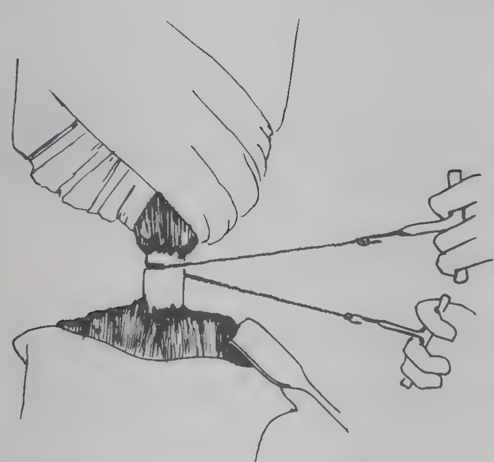

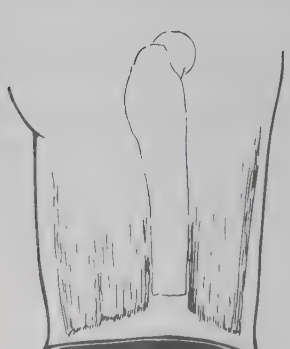

4 Level of bone amputation: Retract the soft tissues and cut off the bone as proximal as possible without dissecting the muscles off their bony attachment. The oozing of blood from the medullar bone is controlled by compression for five minutes by a crammed wet gauze compress. The profile of the guillotine stump should be like an inverted cone.

The problem with guillotine amputation

It is due to the retraction of soft tissues: The skin is elastic and will retract many cm within two weeks. The muscles will also retract progressively and thus pull the fascia and skin further into retraction. Thus the bone may protrude after 1-2 weeks, and further bone amputation may be necessary in order to close the stump. Many sophisticated kinds of skin traction are developed in order to prevent soft tissue retraction. However, they are elaborate, time consuming and not very effective. This is our advice: Restrict the use of the guillotine method. When you use it, apply a well-fitting and tight Trueta plaster cast onto the stump in the primary operation. Providing drainage and preventing edema, the Trueta cast will also reduce the soft tissue retraction to some extent.

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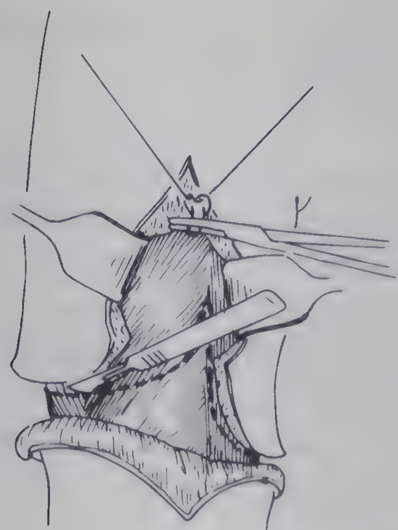

5 Method two – the main method: Flap amputation. We advocate flap amputation as the main method in wartime surgery – because it is a rather rapid method, you save limb length, and it is safer due to a better exploration of the soft tissue injury.

Design the flaps to fit the missile wounds: You may use anterior-posterior flaps, or medial-lateral flaps. Incise the skin and fascia in one stroke. Save all viable skin and subcutaneous tissue: The skin retracts; also it may be needed for the stump closure. Extend the incision on both sides into wide exploratory fasciotomies (dotted line). Explore, debride and resect each muscle belly at the lowest possible level without compromising with viability. Control the main vessels with double ligature. Cut the nerves at the highest possible level; block each main nerve with local anesthetic. Saw off the bone at the main muscle amputation level.

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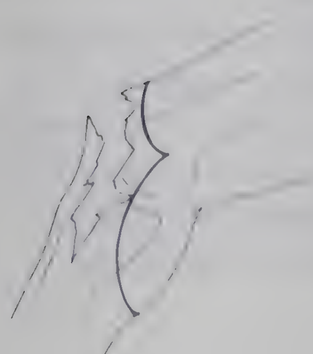

6 Method three – disarticulation (the knee joint): This method is rapid, simple and less traumatic. It is indicated in trapped limbs, emergency amputations in serious cases, and for extensive joint injuries. It is said that the disarticulation results in amputation stumps unsuitable for prosthesis. This is not so: The disarticulated stump is suitable for any modern prosthesis. Design the skin-fascia flaps according to the injury: The standard method is a short anterior-long posterior flap. You may also use medial-lateral flaps. The incision is carried through skin and fascia in one incision.

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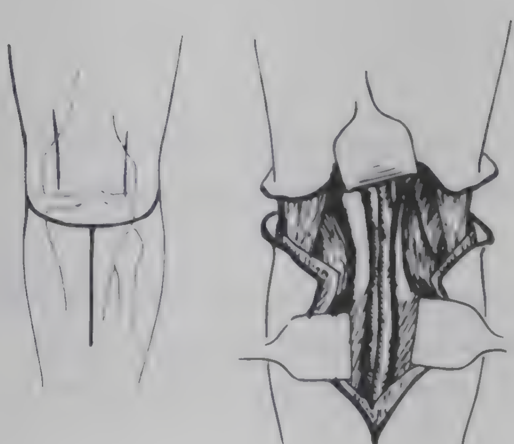

7 Disarticulation – control the vessels before you amputate. Make a wide incision from the amputation level downwards along the main nerves and vessels. Retract the nerves and cut them at the highest possible level; apply local anesthesia nerve block. Ligate the vessels doubly. Then the joint capsule with ligaments and tendons are cut. **Notice:** Some synovium is left on the amputation stump. It will produce fluid – better drain the stump well. There is no problem with soft tissue retraction after disarticulation.

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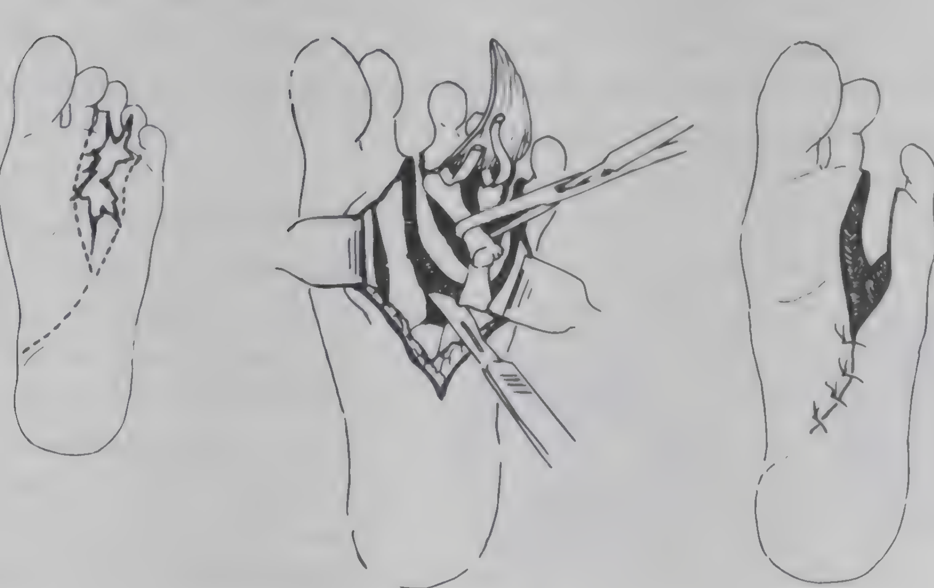

8 Method four – ray amputation on the hand/foot: Compared to a transverse amputation, the ray amputation is less traumatic as the incision runs parallel to and inside the space between the muscles, vessels and nerves. The functional and cosmetic result is also satisfactory. The wound is explored proximal to the level of injury through longitudinal incisions. In high-energy injuries the shock wave may cause muscle necrosis inside the compartments of the calf/forearm: Extend the exploratory incisions above the ankle/wrist. Particularly explore the lateral compartment of the lower leg. Leave these incisions open as fasciotomies. Resect the metatarsal/metacarpal bones

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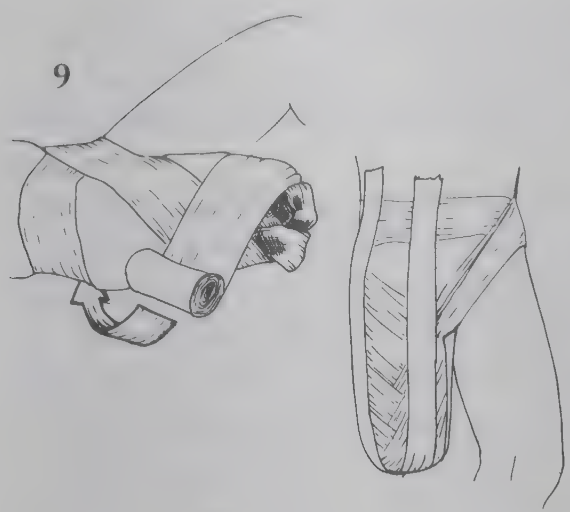


through the joint, through the fracture, or take them off with saw close to their base. The amputation wound will ooze considerably: Drain well.

9 **Dressing the amputation stump** is a part of surgery, and should be done by the surgeon. The dressing should prevent stump edema, prevent soft tissue retraction, prevent joint contracture and allow good drainage. You may use either crepe bandage or a Trueta plaster cast. Apply dry fluffy gauze into all deep spaces and compartments of the stump, including the fasciotomies. Pad the bony prominences, and apply a compressive dressing. Include the joint proximal to the level of amputation to prevent joint contracture. Long slings of adhesive plaster secure the dressing/cast and counteract contractures.

10

10 **Immediate post-operative prosthesis fitting (IPOPF):** This method was developed by a skilled French war surgeon during the 1914-18 First World War. Undeservedly it has been forgotten. IPOPF accelerates the rehabilitation of your amputation patients. During the primary operation, outside the still wet Trueta plaster cast, a light metal prosthetic device is applied. The prosthetic device is fixed by another layer of plaster. This prosthesis cannot bear much weight. However, it can support the balance of an amputated patient when mobilized the first post-operative day upon crutches. And he may do simple maneuvers with a hook-arm prosthesis.

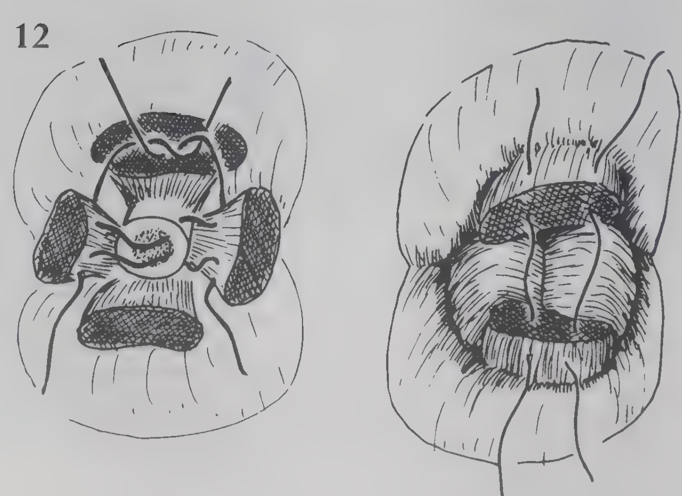
Amputation theory – the elective amputation

The goal of the elective amputation is to close the wound with a minimal risk of infection. And to create a stump suitable for prosthesis, a stump of good shape that can sustain the weight load. **There are some basic principles to consider:**

11

11 **Centering of the bone in the stump:** If the primary debridement has excised the muscles mainly on one side of the limb, the bone will come out of center inside the amputation stump. Also a too short stump will come out of center under weight load. The bone will press upon the soft tissues and cause pain and skin sores.

12



12 **Myoplasty for better muscular control:** To secure the bone in center with good muscular control, myoplasty should be done when the amputation stump is closed: The skin is not separated from the fascia flaps, but retracted as one thick flap. The mass of muscles is divided along the natural septa into four main bundles. The bone is cut and trimmed for

sharp ends. The opposite muscle bundles are fixed to each other by deep interrupted sutures without tension. Thus the bone becomes well centered and well padded. **Notice:** If the myoplasty results in a clumsy stump, the muscles should be "thinned" before the plasty is made (p. 548).

13

13 The skin problem: 4-5 days after the primary amputation the stump should be dressed – and closed if it is clean and well circulated. Do not delay stump closure more than 10 days: The soft tissue retraction will increase and loss of valuable limb length may be the result.

Trim the skin-fascia flaps so that the skin-fascia suture is located off the weight-bearing area of the stump. Central suture lines will create pain inside the prosthesis. **Notice:** Amputation flaps have a maximum length approximately like the base of that flap. If the length exceeds the base distance, the blood nutrition may be insufficient and the end of the flap may become necrotic. Be careful during the dissection of the skin-fascia flaps not to damage their blood supply.

Skin graft for closure? Where the soft tissues have retracted, you may save several cm of stump length by closing the stump with skin grafts instead of re-excision and suture. However, the grafted stump has poor tolerance for weight-bearing. Reserve this method for upper limb stumps and amputation stumps in children. Use meshed thick partial thickness grafts (p. 253).

Nerve entrapment and neuromas

Nerve block during surgery: Apply 5 ml local anesthetic along each main nerve to reduce post-operative pain.

After they are cut, nerve ends may swell and become invaded by scar tissue. Thus a neuroma is formed which may produce chronic pain and excessively tender amputation stumps. Also nerves under tension and pressure may cause painful amputation stumps. During primary surgery identify each main nerve, pull them downwards and cut them as high as possible, let them retract into the soft tissues. Apply non-traumatic technique; use a sharp knife when you cut them. See to it that the soft tissues around the main nerves are viable, that the nerve end is well padded by soft tissues, not under pressure and that no hematoma may collect around the nerve.

Phantom amputation pain

It is a particular pain felt in the amputated limb – in the limb that has been actually removed. Children seldom feel the phantom pain, but approximately 50% of adult amputation patients have some problems with phantom pain – a few of them so intensely that they cannot bear it. Some patients do not feel pain, but a phantom sensation: They feel the amputated limb is still there, and often in a "wrong" position. The phantom problem should be foreseen, your patients and staff prepared on how to handle it:

- A non-traumatic technique during the emergency amputation and the elective amputation will reduce the frequency of phantom problems.
- Inform your patient 2-3 days after the injury that he probably will get some trouble with phantom pain or phantom sensations, that this is a "normal" complication that will gradually recede. Explain to him your plan for further treatment: the time for stump closure, for prosthesis adjustment etc. Information makes him confident and so reduces his pain and depression.

- Early out-of-bed-exercises and application of IPOPF reduce the duration of phantom problems. Encourage his training of the other limbs to divert attention from the phantom limb.

Psychological reaction to amputations

The amputation patient, as do most war wounded patients, has a serious psychological reaction to the limb loss. Especially seen in young male adults and worn-out fighters, this reaction often presents a real psychiatric crisis. There are certain stages in this psychological reaction which you should recognize and take into account when planning his rehabilitation:

- **The initial shock:** This may last 1-2 days after the injury. The patient is not able to realize what has happened to him. Just nurse him well. Do not give him instructions or essential information in this period as he is not able to understand your message.
- **The reaction:** Within 2-4 days after injury, your patient normally realizes that his limb is lost. He becomes depressed and sometimes aggressive. Often he cannot sleep and will not eat. This is the important period for information and psychological support. If you do not respond seriously to his psychological problems at this stage, a lasting mental depression, inactivity, nutritional problems and weight loss will start. The general risk of complications will increase.
- **The reorientation:** The positive signs are his increasing effort during training and his interest for the future, for the family, for the prosthesis service. Try to assist all your patients to reach this constructive stage within three weeks after a serious injury.

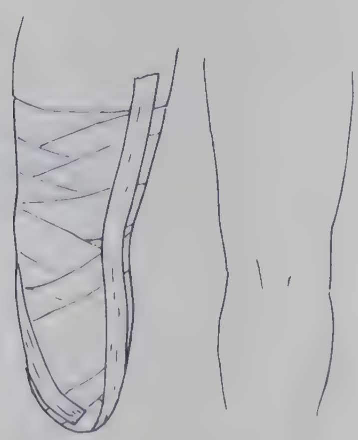
Early prosthesis training

As many as one out of ten of your patients may end up with an amputation. Especially so in mined areas. If there is no prosthesis service available within reasonable reach – make one yourself.

Plan for the initial rehabilitation

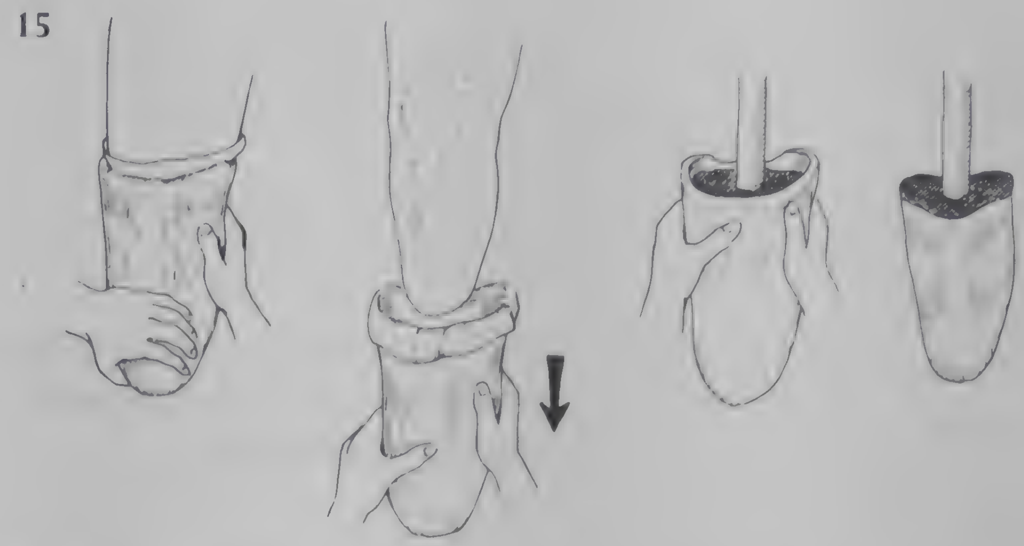
- **Step one:** Apply the temporary light IPOPF prosthesis during the primary operation. Mobilize the patient from the first day after surgery.
- **Step two:** Reapply the IPOPF prosthesis when the amputation stump is closed. Mobilize the patient from the first day after surgery.
- **Step three:** After 1-2 weeks (sutures removed), start anti-edema dressing. Continue IPOPF training.
- **Step four:** When the stump is well shaped – within one month after injury – fit a training prosthesis.

14



14 Anti-edema management: Distal clubbing and edema of a stump will interfere with prosthesis fitting: Wrap the stump several times every day for 30 minutes in a tight elastic bandage to mold the stump into a nice conical shape. Elevate the limb. Active exercises also in bed.

15



15 Make a "negative" copy of the stump: When the stump is well shaped, wrap a plastic sheet over the stump. Pull a stockinette elastic bandage tightly over the plastic sheet. Form a well-molded plaster cast. When dry, remove the plaster carefully in one piece. Fill the plaster form with plastic plaster or mud/grass around a wooden pin. When the content has hardened, remove the outer plaster holster. And you have an exact copy of his amputation stump upon which the prosthesis shall fit.

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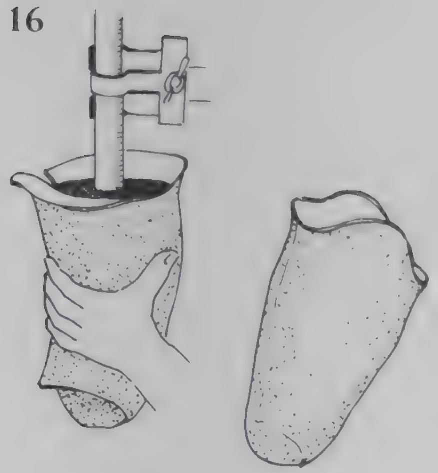

16 Make the inner prosthesis holster: There must be some padding between the skin and the prosthesis holster: Tubigrip stocking is desirable, but home-made elastic textile stocking will do as well. Put this padding upon the stump copy. Then make the inner holster from Orthoplast. Leather may also be used.

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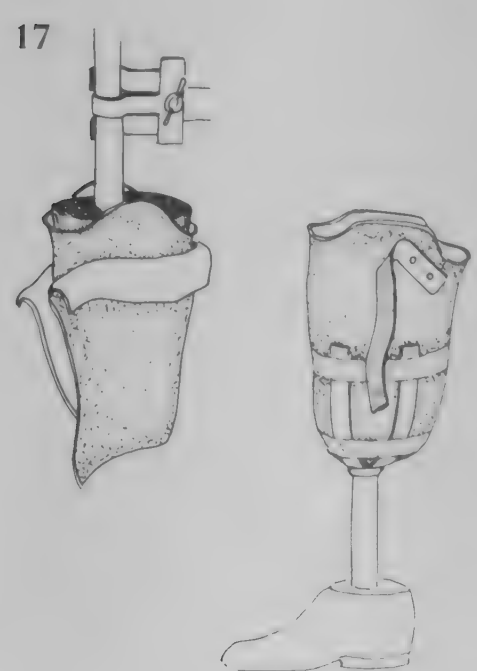


17 Make the outer prosthesis holster: With padding and the inner holster on the stump copy, another sheet of Orthoplast is applied to form the outer holster. To the outer holster you attach the walking device, a carpenter-made hand, a hand hook etc.

18

18 Adjust the prosthesis: Folds and ridges cause pain and pressure sores. Cooperate closely with the patient; adjust and mold the padding and holsters until they fit optimally.

Points to note – Chapter 16

Monitor the war wound
- the wound care in brief: p. 250
- the wound care in detail: p. 578-582
- avoid cross-infections in the bed department: p. 581
- know the common bacterial pattern in different types of wounds: p. 649

Know why some wounds heal poorly
- study the suture technique: p. 164 and 170
- relief sutures: p. 370
- relief incisions: p. 359
- know the main reasons for delayed healing: p. 580
- know the reasons for skin graft failure: p. 573

16 Wound closure

Monitor the wounds

Five reasons not to leave wound management and monitoring for inexperienced staff

- Wound infections may cause serious complications. The only effective therapy is redebridement before organ complications develop. Only by close and expert monitoring of the war wounds, necrosis and infection are diagnosed in due time.
- Regard dressing of major war wounds as regular surgical operations to be done under anesthesia. Be fully prepared for medical and surgical complications.
- The rate of redebridements indicates the quality of your surgery: Increasing numbers of cases with necrotic tissue left over after the first debridement indicate that you also should monitor and advice your surgeons.
- Unqualified wound dressing causes cross-infection from one patient to another, and increases the risk of developing hospital infections (p. 581). Monitor continuously the routines for disinfection and sterile working.
- The daily dressing, monitoring of wounds and redebridements are the most time- and resource-consuming procedure of a wartime clinic. See to it that it is optimally organized.

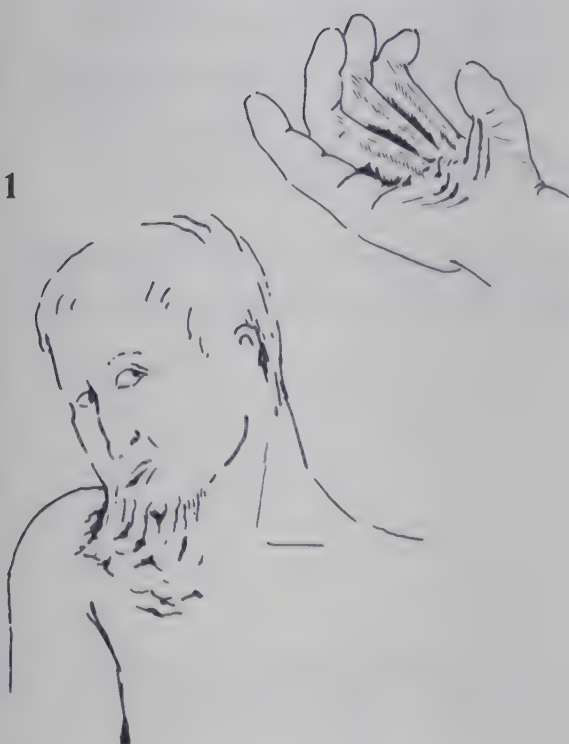
The practical procedure

- **When:** Inspect the wound 4-5 days after the primary debridement.
- **How:** Undress it completely. If gauze drains and debris stick to the wound, soak the wound with hydrogen peroxide solution. Or better still, put the entire limb/patient in soap solution for 15 minutes, and undress it/him there.
- **Whom:** The first dressing should be done by the surgeon or a surgical team member who made the primary surgery.
- **Anesthesia/analgesia:** Do not let pain prevent a proper exploration! Extensive injuries should be dressed in the operation theater under anesthesia. Perform painful bed-side procedures under intermittent, low-dose i.v. ketamine analgesia.
- **Bed-side debridements:** Small and moderate necroses should be excised immediately with scissors or knife.
- **Before skin grafting:** If you want to accelerate the granulation, dress the wound frequently for some days with gauze wet with hypertonic NaCl solution.

Closure by spontaneous granulation

Provided there is continuous good drainage of the wound, the safest procedure for wound closure is to let the wound heal spontaneously with granulations and

scarring. The wound will fill gradually from the bottom without leaving any pocket that may fill with debris and turn into an abscess. But there are wounds that should not heal by spontaneous scarring:



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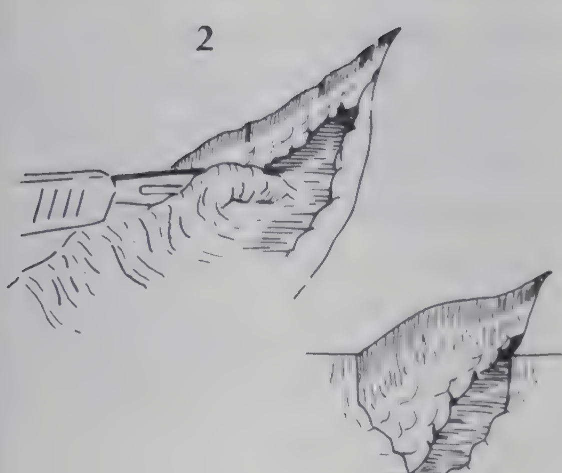
1 **Deep scarring may cause contracture:** Spontaneous healing of full thickness skin wounds (burns) or deeper wounds may cause scar contractures. Early skin grafting is indicated in the face and neck, in particular on wounds close to the eyes and mouth. And in all extensive wounds over/close to joints.

The scar may be painful: Some scar areas are painful to the touch. They may also be painful when exposed to the cold. Besides, as scar tissue is not innervated, you have no skin sensation in a scar field. Therefore, do not let wounds close spontaneously in sensitive body areas (amputation stumps, face, hand or foot).

The scar may hypertrophy or produce keloid tumours: In some patients (and particularly in some African people) the scar tissue turns hypertrophic in any wound: The scar becomes thick, solid and swollen. In some cases the scar production may accelerate even further and produce regular scar tumors – keloids. Hypertrophic scarring is often painful; it is also ugly and it increases the risk of contractures.

Delayed primary suture (DPS)

2



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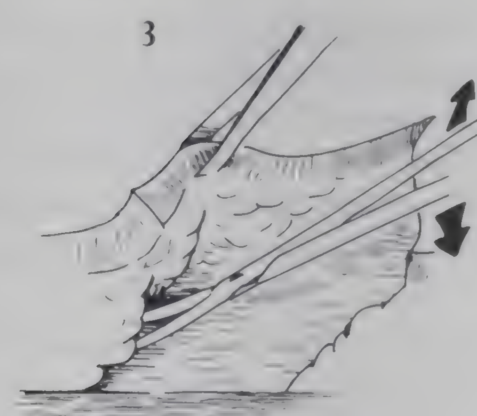

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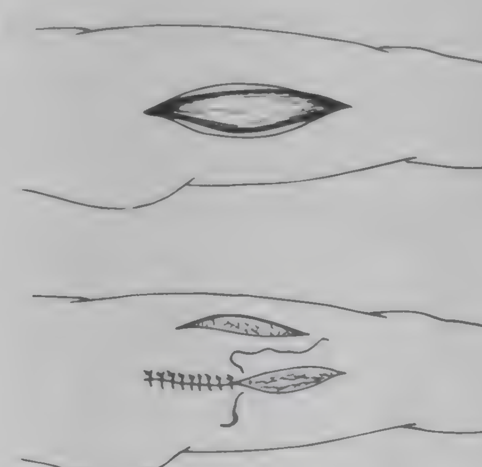


2 **DPS – the main method for closure of wartime wounds:** The condition, without compromise, for DPS is a wound without necrosis and infection. When ready for suture, trim the wound edges down to the fascia with a sharp knife until you identify capillary bleeding from the wound edges.

3 **DPS – mobilize the wound edges:** Tension upon the sutures will make them obstruct the blood supply to the wound edges, and necrosis and infection will develop. Prevent tension by undermining some cm of the wound along the fascia before the sutures are applied.

4 **Relief incisions to prevent tension:** Make parallel relief incisions on each side of the wound (here – closure of a fasciotomy), approximately 5 cm from the wound. The relief incisions should not be sutured – let them heal spontaneously.

Some practical points

- You may close the muscle, fascia, subcutaneous fat and skin in four separate sutures.
- Note that the suture materials – particularly the absorbable ones – cause some chemical irritation to the tissues. In "risky wounds" better close all layers of the wound in one suture – narrow interrupted mattress sutures are convenient.
- To reduce the tension on each suture, set the sutures at maximum 1 cm intervals.
- Deep pockets inside the wound may be closed separately with a few absorbable sutures. But a safer procedure is to delay the DPS until such pockets have filled up with granulations.

Basic suture techniques: p. 171

Skin grafts

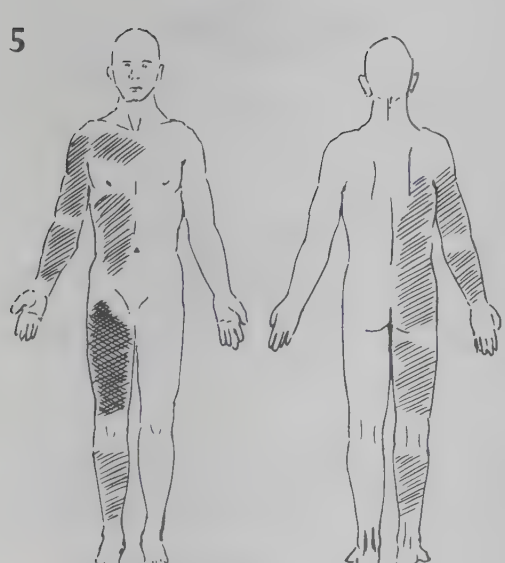
They have no blood supply; they are not innervated. **Skin flaps** have blood supply and innervation.

Types of free skin grafts

The anatomy of the skin: p. 558

- **The thin partial thickness graft** includes only the most superficial layer of the skin. It has good "take", but the skin of the grafted area becomes thin and fragile. The donor site will granulate rapidly.
- **The thick partial thickness graft** – only the deepest layer of the skin is left on the donor site. This graft has impaired "take" and parts of it may become necrotic. But the final result is a nicer and more resistant skin.
- **The full thickness graft** includes all layers of the skin down to the subcutaneous fat (p. 254). This graft gives the best final result. But there are problems with the "take": Graft necrosis often occurs in more than minor full thickness grafts. Minor grafts to a well-vascularized bed (the face) succeed when there is no infection.

5



Conditions for grafting

- The wound has healthy granulations. See p. 573 and 579.
- The wound is without infection.
- The grafted area must be immobilized for 5 days after grafting.

Partial thickness skin grafts

5 Donor areas for partial thickness grafts: The shaded areas are the common sites from where to take partial thickness skin grafts. If the grafts are very thin, and if the donor site heals well, you may take grafts from the same area every 8-10 days. Working on hand injuries, you may well take minor grafts (with scalpel) from the same hand.

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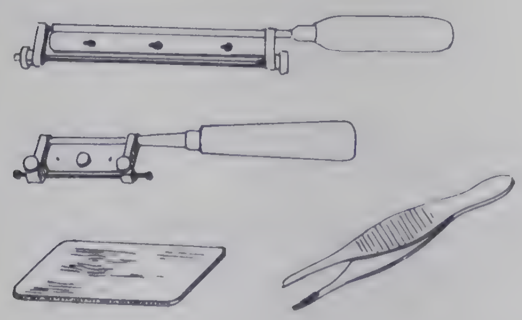
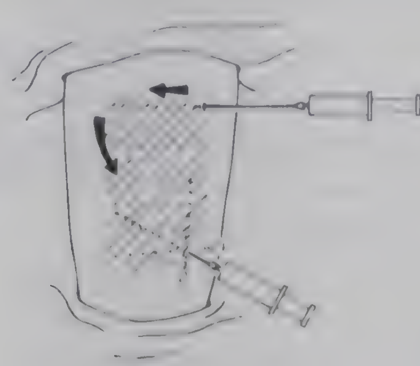


6 **The instruments for skin grafting:**

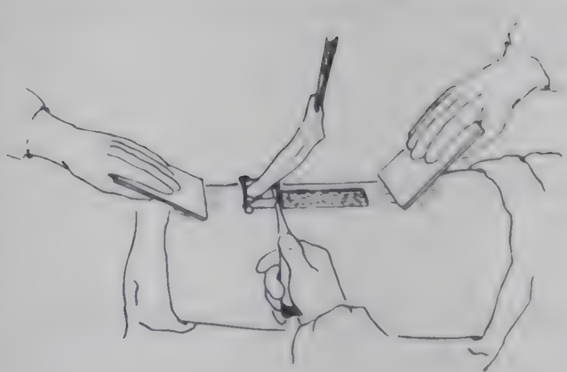
- Large dermatome (15 cm), adjustable for any thickness of skin grafts.
- Small dermatome with standard razor blades, adjustable for any graft thickness. Convenient and sufficient for most grafting procedures.
- A plain wooden plate 15x10 cm, to stretch the skin when the grafts are excised.
- Fine non-toothed forceps.

7



7 **Anesthesia of the donor area:** If you fix the partial thickness grafts with sterile adhesive plaster (ill. 9), the entire grafting operation can be done with infiltration anesthesia of the donor area only.
Spinal needles are convenient.

8



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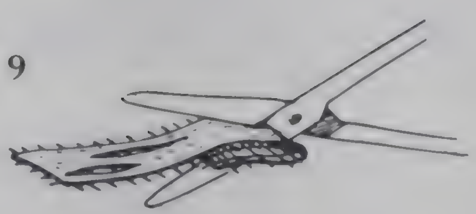

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8 **Split-thickness grafting – the procedure:** Adjust the dermatome to excise exactly the graft thickness needed. Stretch the donor site between the wooden plates. Pick up the graft with the forceps so it does not become trapped in the dermatome. **Notice:** Grafts wider than 5x10 cm are difficult to handle.

9 **The graft preparation:** Put the grafts with the skin side down on a sheet of vaseline gauze – that makes them more easy to handle. Trim their edges and **mesh** them: Cut some short incisions in each graft to prevent fluid from collecting under the graft and lifting it off its bed. **Notice:** Do not let the grafts dry; wet them with normal saline until they are applied.

10 **The grafting:** Put the grafts, a few mm apart on the bed of granulation, their flesh side down. You may fix them by some interrupted sutures, but it is easier done with thin strips of sterile adhesive.

Dressing

- **Either closed treatment:** Dress the wound with normal saline-moist gauze, thick gauze padding and good fixation with broad crepe bandage.
- **Or open treatment:** Apply no dressing at all; let the graft be exposed to the sun's heat during the day, or dry it carefully at intervals with a fan or hand heater (hair dryer). Open treatment improves the graft "take" and should be applied for full thickness grafts and face wounds. It is contraindicated in dirty and infected areas.

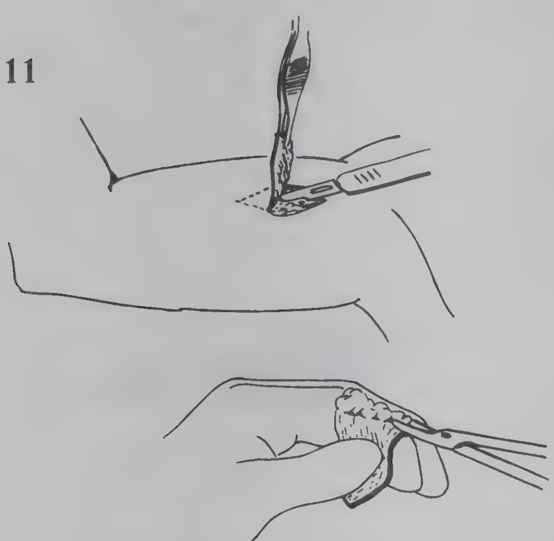
Allografts may carry HIV.

Grafts as dressing

Thin partial thickness skin grafts are the best dressing possible – they stimulate healing and help prevent wound infection.

- **"Bank grafts":** Take some thin partial thickness grafts during the primary debridement, and put them on vaseline gauze moist with sterile normal saline in a sterile closed glass inside the refrigerator. You may apply the bank grafts for that same patient when the wound is examined 4-5 days after surgery – either to close parts of the wound or as dressing until definitive wound closure is done.
- **Allografts:** You may use the bank grafts on some other extensively injured patient, that is, as allografts. Allografts will not take, but become necrotic after 5-7 days. But during these days they are an excellent dressing.

11



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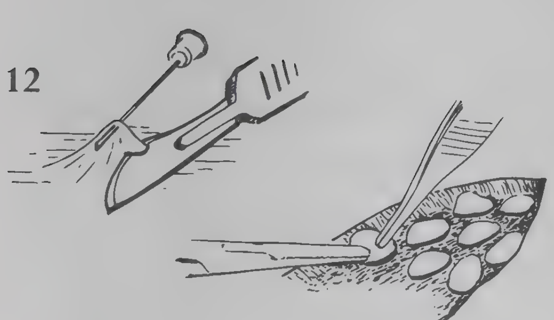

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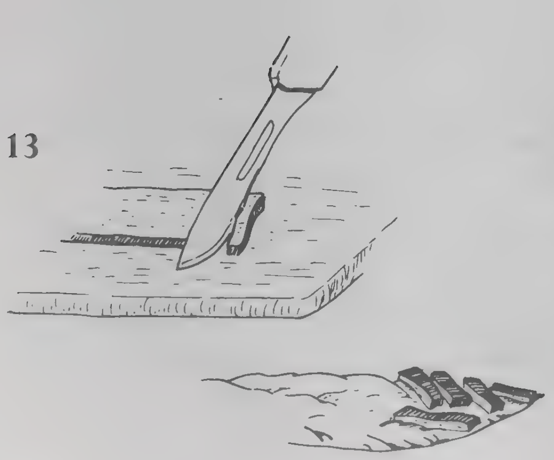


Full thickness skin grafts

- should be used on wounds where resistant skin cover is needed (finger pulp)
- on cosmetic indications (eyelids, face wounds)
- in children (better graft "take")
- but only on small wounds.

Full thickness grafts may be applied as continuous grafts, pinch grafts or corachan grafts:

11 **Continuous full thickness grafts:** Take the graft from non-hairy areas (forearms or neck). When you design the graft size in the donor area, take into account a 20-30% retraction of the graft when it is raised out of its bed. Raise the graft by careful sharp dissection in the sheet between the skin and the subcutaneous fat. Remove all subcutaneous fat from under the graft and mesh the graft if you want to apply it as a continuous graft. Trim it to fit the wound and fix it to the wound with non-traumatic sutures (Donati, p. 171). Apply either open treatment, or a compressive dressing to avoid fluid collecting under the graft and lifting it off the wound granulations. The donor site is closed by direct suture. Redress the graft very carefully after one week. If parts of the graft seem necrotic but are still attached to the wound, the "take" is partial – do not remove the graft: New skin will develop from elements of the skin tissue even in areas where the "take" is only partial.

12 **Pinch full thickness grafts:** The pinch grafts have good "take", but poor cosmetic result. Lift a small skin cone and cut it (knife blade horizontal). Each pinch is thin at the edge while the center is thicker containing skin germ cells. New skin will develop between the pinch islands from these germ cells. Dressing with vaseline gauze, moist gauze and slight compression. The donor site will heal by spontaneous granulation.

13 **Corachan full thickness grafts:** Dissect a full thickness skin band and remove all subcutaneous fat. Cut the graft in small stripes and place these **side down** on the granulation bed, side by side. The corachan grafts have better "take" than the pinch grafts. Close the donor site by direct suture.

Skin grafts upon bone

It is essential to cover exposed bone in order to prevent infection and stimulate fracture healing. The best method is muscle rotation flaps (p. 200). Small areas of raw bone may also be grafted with free grafts – provided the area is without infection: Drill multiple holes through the cortical bone into the marrow. Dress the area with gauze wet with hypertonic NS solution for some days. Granulations will develop from the marrow through the drill-holes, and make a bed for grafting. Apply a thick partial thickness free graft or corachan grafts.

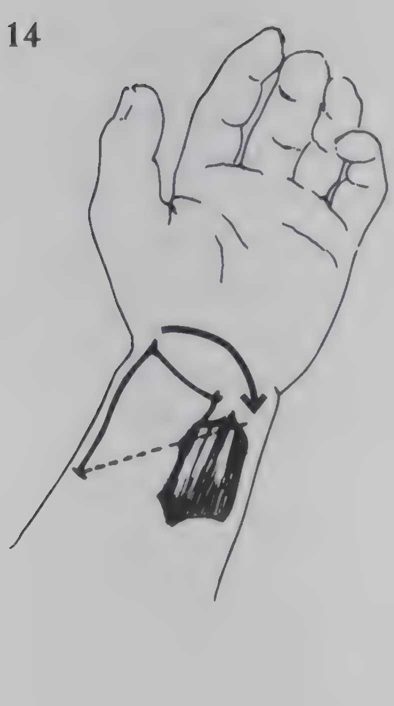
Skin flaps

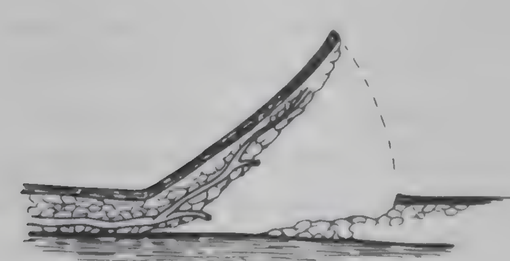
Dissect the flaps to include subcutaneous tissue with nerves and vessels. Thicker flaps may also contain fascia and muscle – myocutaneous flaps, p. 201.

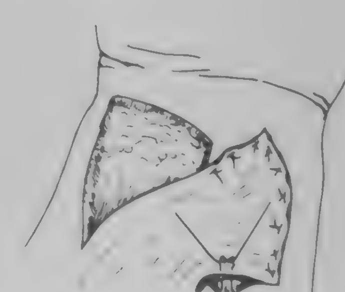
The positive effects of flap closure:
- A correctly designed flap has good blood supply and venous drainage, and helps prevent wound infection.
- Flaps provide better soft tissue padding of the wounded area.
- As flaps are innervated, the sensory function is not lost.

Consider flap closure in these cases
- Full thickness skin loss on the palmar side of the hand, fingers and foot
- Large wounds where tendons, nerves and vessels are exposed without soft tissue cover
- Full thickness skin loss close to the eyes and mouth
- Skin deficit or poor soft tissue padding on amputation stumps
- Extensive soft tissue and full thickness skin loss after debridement

14







14 Local flaps – the rotation skin flap: Plan and design the flap before the dissection starts. **Notice:** Good venous drainage from the flap is important. Design the flap along the veins of that area so that the flap drains well through its base. **Notice:** The flap will shrink when it is raised from its bed. Take 20% shrinking into account when you design the flap size. **Notice:** The cm length of the flap in relation to its base should not exceed 1.5:1. Otherwise the end of the flap may become necrotic. A face flap may be somewhat longer because of the good blood supply.

Raise the flap by careful sharp dissection towards the muscular fascia. Do not damage the superficial veins. The base of the flap should be thicker than its end. Rotate the flap, trim its size and fix it well with fine non-traumatic sutures. **Notice:** If too much tension arises along the long axis of the graft, make a very short transverse relief incision at its base. The donor site is covered by free skin grafts.

15

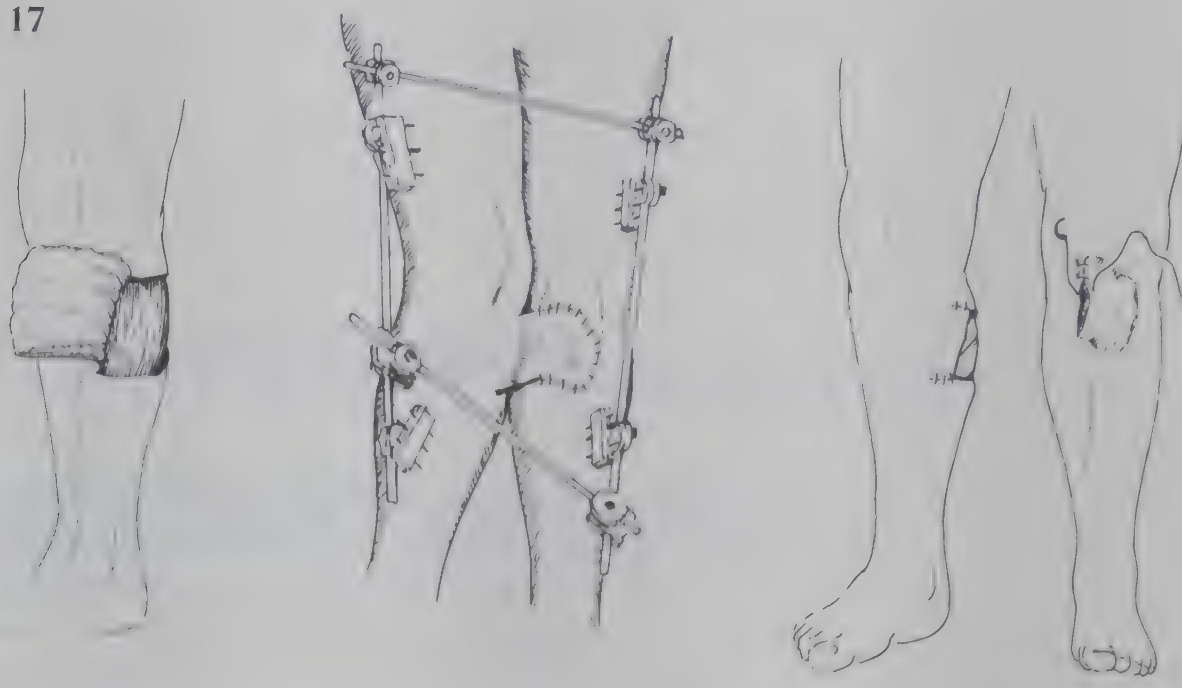
15 Local flaps – the composite rotation flap: You may further cut the bone of this stump, and close it by direct suture. But you lose length – and the important grip function of the hand. To save length in finger amputations, composite flaps should be used. A flap is raised composed of skin, subcutaneous fat, vessels, nerves, fascia – and the short intrinsic muscle to the 2nd finger. The flap is trimmed and sutured to the defect. It provides good soft tissue padding for the bone, complete sensation – and the grip function is saved.

Sliding finger flaps: p. 509
Sliding face flaps: p. 335
Tunnel flaps: p. 510

16

16 Distant flaps – the cross finger flap: You may transfer skin flaps from one area to another – distant flaps. This full thickness skin injury on the volar aspect of the index finger will cause joint and tendon contracture by spontaneous healing. A broad-based flap of skin and subcutaneous tissue – not including the volar nerves and vessels – is raised from the lateral aspect of the 3rd finger. The flap is trimmed and sutured to cover the defect on the index finger. The donor area on the 3rd finger is covered by thin split-thickness grafts, and the two fingers are immobilized together. After 10-12 days the flap will take its blood supply from the index finger, and you may cut it through its base on the 3rd finger, trim the cut edge and close the index finger wound.

17



17 Distant flaps – the cross leg flap is well nourished, and drained from the saphenous vein. Its main indication is to provide soft tissue cover to lower leg fractures with extensive loss of soft tissues. Be aware that nursing patients with the cross leg flap is demanding. The flap is designed on the healthy leg with an anterior base just posterior to the saphenous vein. The skin and soft tissues are raised down to the fascia, the flap trimmed and sutured to the wound on the opposite leg. The flap bed is covered with split-thickness grafts. The legs are immobilized in a convenient position with external fixation apparatus or double plaster casts with transverse wooden bars. After 10-12 days the flap is divided, trimmed and sutured along the medial edge.

Other distant flaps –
the groin flap: p. 508
The abdominal flap: p. 201
The forearm flap: p. 510

For safety – control the flap circulation! For major flaps we recommend a two-step operation

- **First step:** Dissect the flap, dress it with moist NS gauze under the flap.
- **The second step:** The next day inspect the capillary circulation at the tip of the flap. If its skin is warm with good color, transfer the flap. If there is edema, pale and cool skin the flap will turn necrotic within days: Replace it to its bed, choose another strategy for wound closure.
- **In distant flaps:** After 10 days, before dividing the flap, compress the flap base for some minutes and monitor the flap circulation. If the flap maintains good circulation during compression, it is well circulated from its new bed: You may divide the flap through its base.

Points to note – Chapter 17

Examine the injured child carefully

- the clinical signs of breathing problems may be few, do not miss them: p. 260
- note the normal values of blood pressure and heart rate in children: p. 261
- know how to manage circulatory shock in children: p. 262

Know why the old, injured people need early basic life support: p. 264

17 Injuries to children and old people

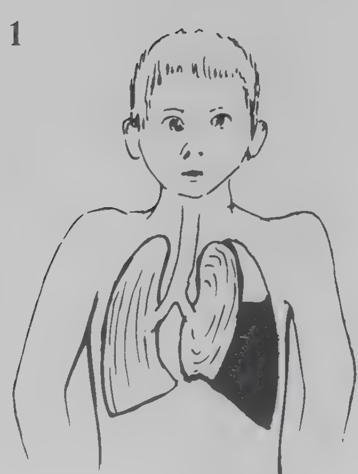
Basic life support and surgery in children

For the triage, clinical examination and medical support for injured children, follow the general principles discussed in Chapters 2, 6 and 7. But on certain points the management of war wounded children differs from that of adults. Only those particular features are discussed below.

Respiration

- **Do not obstruct the nasal airway:** Small children breathe mainly through their nose. Injuries of the midface with fractures or blood clots obstructing the nasal airways will impair the respiration and cause stress. Clear the obstruction by suction and prompt reduction of fractures. Or perform tracheal intubation or needle laryngotomy. Tubes for gastric decompression and enteral feeding are not inserted through the nose but through the mouth.
- **Abdominal injury impairs the respiration:** Children's ventilatory work is mainly done with the diaphragm, less with the chest. Abdominal pain, high abdominal injury and injuries of the diaphragm will impair the respiration. Gastric distention after injury or after intensive crying may also impair their respiration. Use mouth-stomach tubes for decompression on ready indications.
- **Emergency laryngotomy: Use needles!** Upper airway obstructions are best managed by insertion of 2-3 large-bore needles into the larynx between the cricoid and thyroid cartilages. Laryngotomy incisions may cause secondary stenosis and should not be done in children.
- **Prompt chest tubing!** The mediastinum of children has poor resistance; a small hemothorax or pneumothorax may shift the mediastinum into the opposite hemithorax and cause compression of the uninjured lung.

1



1 Mediastinal shift after hemo/pneumothorax in children: The mediastinum of children is soft; it is shifted to the opposite side after injury. Both lungs thus become compressed and the respiration impaired. Early insertion of a chest tube prevents this mediastinal shift.

2

2 Avoid bronchial intubation – locate the end of the tracheal tube: The trachea of small children is short, the distance from the vocal cord to the main bronchus is only 6 cm in a one-year-old child. Be careful the endotracheal tube does not enter one main bronchus, leaving the opposite lung without ventilation. In children the tube is palpated through their soft trachea: The end of the tube should not be located below the level of the clavicular heads. As a routine, chest X-ray is done after intubation to check the tube position.

Table 1
Tracheal tube size for children

Age (years)	Internal tube diameter (mm)	
Newborn	3.0	no cuff
1	3.5-4	no cuff
2	4.5	no cuff
2-10	$\frac{AGE + 16}{4}$	no cuff
10-15	6.0-7.5	cuffed

A guideline: The child's 5th finger corresponds approximately to the endotracheal tube size for that child.

Circulation

> Do not give drugs to the hypovolemic child that may decrease his PR: His tachycardia is the main protection against circulatory failure.

- **The clinical signs of circulatory shock are poor:** Children do not respond to severe hypovolemia by a decrease in BP. The main signs of serious internal bleeding are high PR and decreased peripheral circulation with cool limbs. The signs of moderate hypovolemia in children may be very subtle: Look for the silent, unresponsive child with cool nose tip and some tachycardia; he may have lost as much as 20% of the blood volume.
- **The compensation for hypovolemia is poor:** The child's renal function does not respond to circulatory shock by increased resorption of sodium and increased concentration of urine, as does the adult's. Also the child has less capacity to draw tissue fluids into the circulation to maintain an adequate blood volume. The silent child with moderate hypovolemia may suddenly develop grave circulatory shock if an early diagnosis is missed and volume therapy is delayed.
- **Standard physiological values of children differ much from adults!**

Table 2
Normal values for children

Age (years)	**1-2**	**5-7**	**12-14**
Blood volume ml/kg	90	80	70
Pulse rate less than	160	140	120
Blood pressure higher than	80	90	100
Respiratory rate less than	40	30	20

Volume therapy of children

- **Step 1:** Insert double i.v. cannulas before the peripheral veins collapse. To ease the procedure, wrap the child in warm clothes and put warm wet clothes around the limb before cannula insertion. Do not hesitate to perform cut-downs. Cut-down is done in veins of the lower limb, upper limb or in the external jugular vein. In small children standard large-bore venous cannula may be used as venous catheters after cut-down. The femoral vein may take the infusion set tube as venous catheter after cut-down in even small children.
- **Step 2:** Insert bladder catheter. The urinary output after effective volume therapy should exceed 30 ml/kg body weight during 24 hours.
- **Step 3:** Give 20 ml/kg body weight NaCl as rapid infusion. The infusion must not be cold! Monitor his vital signs and urinary output. If he does not respond to this infusion – or if he responds but deteriorates again – proceed to step 4.
- **Step 4:** Give another 20 ml/kg NaCl infusion and observe. If he still does not respond, he needs blood transfusion. Proceed to step 5.
- **Step 5:** Give 20 ml/kg O-negative blood or type specific blood. You may use uncross-matched blood from the mother to babies less than one week old. (Direct transfusion: p. 270). If his circulatory state is still not stable, he needs urgent surgery.

Prevent hypoglycemia

Small children have small depots of glycogen, and serious injuries may cause hypoglycemia. Monitor their blood glucose closely. Use dextrose-NaCl infusions for volume therapy in small children.

Prevent hypothermia – also in hot climate

Hypothermia may cause secondary complications: poor cardiac performance, poor response to volume therapy and tendency to increased bleeding. The injured child must actively be kept warm during the evacuation as well as during management at the clinic. The younger the child, the higher is the risk of hypothermia. The risk cases are

- Major open injuries
- Extensive burns
- Starved children
- Massive infusions
- Prolonged evacuation and major surgery.

Particular features of surgery on children

Chest injury

- Early diagnosis of hemo/pneumothorax and prompt chest drainage may be life saving. Perform fine-needle diagnostic pleural puncture on the slightest suspicion – aspiration of blood is diagnostic.

- The chest wall of children is soft and multiple rib fractures are not common after crush injuries: Blunt injuries may cause lung contusions without the ribs being fractured. Children rescued from entrapment situations and children with contusion marks on the chest should be kept for 1-2 days for respiratory monitoring – even if their respiration may seem easy on admission.

Abdominal injury

Diagnosis, exploration and management of specific organ injury in children follow the guidelines in Chapters 26-36 – with some exceptions:

- The chest cage is short and the abdomen wide in small children: High abdominal organs such as the stomach, duodenum, the small gut, liver and spleen are more exposed to injuries than are adult organs. Poor respiration, internal bleeding or bloody drainage from the stomach even after "minor" blunt injuries are indications for surgical exploration of the upper abdomen.
- Bleeding from the liver and spleen may stop spontaneously in children. Contrary to injured adults, splenic injuries in children may thus pass without diagnosis. The capsule of the spleen in small children is thick compared to adults, and may take sutures. Tears of the spleen may therefore be managed by debridement and careful suture.

Basic life support and surgery in old people

Old people have poor physiological reserves to respond to a major injury:

- Their respiratory capacity is decreased
- Their cardiac performance is decreased
- They have poor defence against infections
- Early as well as late organ complications after major trauma are more common than in younger patients

Careful medical stabilization as soon as possible after injury may reduce the risk of secondary complications.

At triage: Give general priority to the elderly. Their risk of complications will increase rapidly if proper management is delayed.

Respiration

- **Watch for hypoxemia:** Aging causes increased lung stiffness and reduced vital capacity. In old patients the respiration may be marginal before injury – and even a minor depression of their respiration may cause poor tissue oxygenation.
- **Watch for pneumonia – gram-negative pneumonia is a common fatal complication after injury in the elderly:** Aging and alveolar dilatation cause emphysema with retention of airway secretion and increased risk of

atelectasis and pneumonia after injury. There is increased risk of aspiration in old patients that further contributes to respiratory problems.

Circulation

- **Poor response to hypovolemia – start early volume therapy:** The old heart cannot respond to hypovolemia by adequate increase of the heart rate – the cardiac output will fall more rapidly than in younger patients. Neither are the peripheral vessels fully capable of constriction and shunting of blood to the vital organs as a response to bleeding. As a consequence volume therapy should be started early – before the circulatory shock is evident.
- **Risk of fluid overload:** The volume therapy should be done carefully to avoid too high fluid loads, fluid retention in the lungs and impaired respiration.
- **Give cardiac support:** Secondary to major injury there is an increased risk of cardiac arrhythmia and infarction due to cardiovascular disease commonly seen in old patients. Analgesics and oxygen mask for all serious cases are important cardiac support.

Surgery on elderly

- **Triage:** Early primary surgery is especially important in the elderly – delayed definitive surgery will increase the mortality rate considerably.
- **Infections:** Poor peripheral tissue perfusion and a general low resistance to bacterial infections make old patients a risk group regarding wound infections. Two measures will reduce the rate of infections: **First** – restore the tissue blood circulation by early volume therapy, prevent local edema, consider fasciotomy on wide indications. **Second** – make debridement as soon as possible. It is a sad fact that old injured patients are often the last ones to be evacuated after mass casualties and accidents.
- **Head injuries:** Old patients have increased risk of skull hematoma formation after a head injury; even a minor blunt head injury may cause a subdural hematoma. Monitor closely for 2-4 days after head injury. The surgical management follows the guidelines discussed in Chapter 23.
- **Chest injuries:** A penetrating chest injury is managed by early chest drainage. The mortality of blunt chest injuries is much higher in patients older than 65 years. Blunt injuries may cause multiple rib fractures or sternum fracture with "flail chest" formation. Early diagnosis and respiratory support are essential: analgesics, costal nerve block, tracheal suction, coughing exercises, early ambulation. Increasing RR and hypoxemia are indications for intubation or tracheostomy and assisted ventilation.
- **Limb injuries:** Due to osteoporosis (bone demineralization), the elderly are prone to get fractures of the spine, the pelvic ring or the long bones even after moderate injuries. The fracture hematoma may be considerable after pelvic fractures, even life threatening. The fractures of the old patient heal slowly and there is increased risk of non-union and osteomyelitis. The debridement after missile fractures should be done soon after injury with meticulous exploration, not leaving any necrotic tissue in the wound field. Due to the poor tissue blood perfusion in the elderly, consider primary amputation after open comminuted fractures – in particular if there is associated vascular injury.

Points to note – Chapter 18

Assess how much blood is lost

- know the clinical signs of circulatory shock in adults: p. 107
- know the clinical signs of circulatory shock in children: p. 108
- note how much blood is lost in some common fractures: p. 108
- know the objective of volume therapy: p. 147

Emergency transfusions are done with O-negative blood

- note the transfusion procedure: p. 269 and 706
- note the side effects of transfusions with O blood: p.269

Autotransfusion may be life saving: p. 153

Blood transfusions may increase the tendency to bleed

- warm the blood before transfusion to prevent hypothermia; cold blood platelets do not stop bleeding: p 131 and 271
- only fresh whole blood contains blood platelets: p. 268

Notice the risk of blood-transmitted diseases: p. 271, 288, and 290

18 Emergency blood transfusion

Reasons for blood transfusion

> **Strict indications!**
> In certain regions serious blood-carried diseases are endemic (AIDS, hepatitis etc). The indications for transfusion in these areas should be very strict.

Anemia
Transfusion should be done if hemoglobin level is below 7-8 g/100 ml – and if the anemia gives rise to clinical symptoms. There is no fixed limit below which transfusion "must be done". A patient may well undergo surgery with a hemoglobin level of 7 g/100 ml if his anemia is chronic, having developed over time. Another patient may be a risk case for surgery if his anemia of 7 g/100 ml has developed acutely or over a few days.

Circulatory shock
- **Individual indications:** The indications for transfusion vary from case to case. Eg. old people have less capacity to compensate for hypovolemia with electrolytes only: Major injury cases should preferably be transfused before or during surgery. Eg. hypovolemic patients with chest injury, respiratory failure or cardiac failure may need transfusion to maintain tissue oxygenation and avoid complications.
- **Grave hypovolemia due to heavy bleeding** is a clear indication for blood transfusion.
- **Internal bleeding not under control** indicates need for urgent transfusion.

Total circulating blood volume: 5 liters or 7% of the body weight (adult male). 1500 ml blood or 30% of total blood volume may be lost before his pulse rate rises and his BP decreases. But children are different: p. 108.

Practical guidelines
One unit of blood lost is compensated by 3 units of electrolytes. A blood loss of 1500 ml is thus compensated by 1500 × 3 = 4500 ml Ringer or NaCl infusion.
- **Moderate hypovolemia:** In most cases a blood loss of 1500-2000 ml blood/ 20-30% is well compensated for with electrolyte infusions.
- **Serious hypovolemia:** Start volume therapy with Ringer flush infusion through double i.v. lines. If his circulatory state does not stabilize promptly and permanently as a response to 3000 ml NaCl infusion, blood transfusion (or plasma expander) is indicated.

The volume therapy in detail: p. 148.

Emergency blood transfusion

Fresh whole blood: Blood used within 3-5 days after drawing.

Fresh whole blood is best
Fresh whole blood from the refrigerator still contains most of the platelets and coagulation factors. Even better is warm fresh blood transfused directly after drawing. After storage in the refrigerator for two weeks, the whole blood has

lost most of its coagulation factors and platelets. Still it may well be used for volume therapy and in the treatment of anemia. But its capacity to control bleeding in trauma patients is poor.

"The walking blood bank"

Also see p. 707.

Fresh whole blood or warm blood is seldom available from major blood banks. In small wartime clinics better organize the local population and let your medical staff register their blood types. Thus organize a local blood pool from which warm fresh blood can be drawn without delay in emergency cases and mass casualties. If you also identify the blood type of the local fighters and the civilian population of your area and let them carry their blood-type card around their neck, the time loss during emergency transfusions is further reduced.

Uncross-matched blood

Cross-matching: p. 707.

Blood packs with ABO- and Rh-type classification are called type-specific blood. In most trauma cases you are not in such a hurry: You can afford the 20-30 minutes it takes to identify the ABO-Rh blood type of your patient and cross-match his blood in relation to type-specific blood bank units.

In emergency cases you may safely use type-specific uncross-matched blood. You will just have to wait the 10 minutes it takes to identify the blood type of the injured patient. If his blood type is already identified, you may start transfusion without delay on admission.

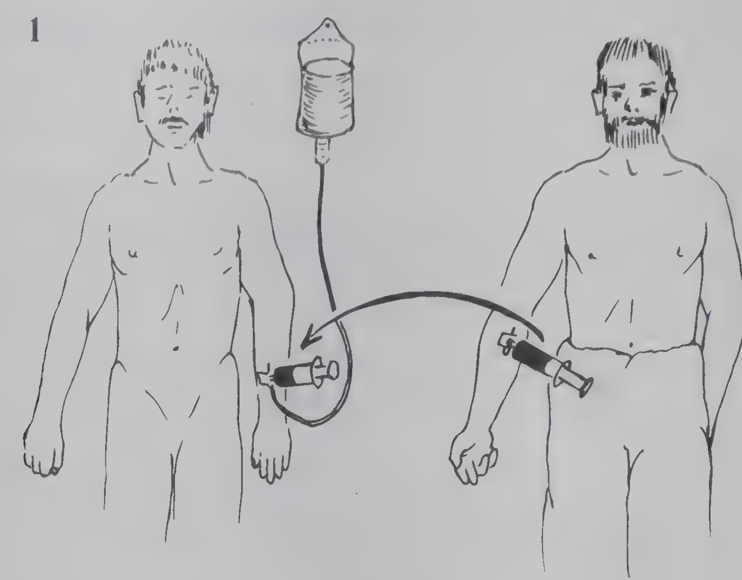
O-negative blood

The distribution of ABO types varies between regions and ethnic populations. In most areas the O-type is common.Check the distribution of ABO blood types of the population in which you work. You may draw 5-10 packs of O-Rh negative blood and store them in a plain refrigerator in the emergency room of your clinic. In general you may use O-Rh negative blood for transfusion to any blood type without cross-matching.

Precautions

- If more than 5 units of O-negative blood are transfused to a non-O patient, transfusion reactions may occur and you have to discontinue the transfusion. If less O-negative units are given, those reactions are not common.
- If you have the blood bank facilities available, the O-negative blood should be analysed regarding anti-A and anti-B antibodies. Preferably only O-negative blood with low antibody-titers should be used for emergency transfusions, as that will further reduce the risk of transfusion reactions.
- Or you may centrifuge the drawn O-negative blood and just use packed red blood cells for emergency transfusion.
- **Notice:** A blood sample from the patient is taken for blood-type identification immediately upon arrival, and before the transfusion is started. If more than 5 units of O-negative blood are given to a non-O patient, there may be problems with later cross-matching of type-specific blood transfusion for that patient.

1



1 Improvised direct blood transfusion: When standard equipment for transfusions are not available you may improvise direct transfusion in emergency cases. Use a O-negative donor or type-specific uncross-matched blood. Double large-bore i.v. cannulas are inserted in the donor veins from which blood is taken with ordinary 20 ml syringes. The blood is administered directly through i.v. cannulas to the actual patient. With double cannulas, two officers may transfuse 500 ml blood during 15 minutes in this way. **Notice:** There is a certain risk of air embolism with this procedure. Let the blood fill the syringes slowly to avoid air bubbles. If the blood is transfused immediately and within seconds, it will not coagulate inside the syringe. If available infuse the blood through micropore filters.

Autotransfusion

> With autotransfusion there is no risk of transmitted blood-borne diseases or transfusion reaction.

In autotransfusion blood from the wounds, abdomen, chest or drains of the injured patient is collected, anticoagulated and reinfused to the patient. Cases suitable for autotransfusion are
- Heavy internal bleeding
- Heavy chest tube bleeding
- Dependent drains producing much blood after surgery

The practical procedure

Special devices for autotransfusion are commercially available.

Blood is collected from the abdominal cavity or chest by a simple sterile mechanical sucker, or a large syringe; or you may collect it with a metal cup or spoon. Leave the blood clots. Filter the blood through a micropore filter or sterile gauze clothes into a sterile bottle. Add 20 ml sodium citrate to each 100 ml blood for anticoagulation. The blood may either be transferred to an ordinary blood pack and transfused or stored in the blood bank as full blood or

packed red blood cells. Or it may be directly transfused with syringes as citrate-blood from the bottle. Reinfuse through micropore filters to reduce the risk of complications.

Complications to autotransfusion

- Precautions in abdominal injury: Blood from the abdominal cavity should not be used in patients with perforations of the large gut. The risk of septicemia is insignificant in cases with minor small gut injuries. As precaution, use broad-spectrum antibiotics as prophylaxis during autotransfusion in abdominal cases.
- Coagulation system failure with increased tendency of bleeding is seen after extensive autotransfusions.
- There is some risk of air embolism if the improvised method is used, but the risk is insignificant compared to the advantages of this method.

Complications of blood transfusion

> There are many and serious side effects of blood transfusion. The risk of complications is further increased during emergency situations and mass casualty management.
>
> Prevent transfusion complications by restricting the use of blood transfusions. Most major trauma cases are managed by electrolyte infusion, plasma expanders and autotransfusion.

Some degree of transfusion reaction is seen in 5% of all transfusions.

- **Transfusion reactions – blood incompatibility:** Within minutes after the transfusion is started, the patient becomes restless and starts shivering, the temperature may rise, urticaria or bronchospasm may develop. These are clinical signs of blood incompatibility as the patient reacts against the tranfused red blood cells (seldom), or against the transfused proteins or white blood cells (common). In most cases the clinical signs will disappear when the transfusion is stopped. In severe cases the reactions are managed by i.v. antihistamines, adrenaline or steroids.
- **Blood-transmitted diseases:** There is a certain risk of bacterial contamination of the blood packs. The risk is increased during laboratory manipulation, production of plasma, packs of red blood cells etc. Staphylococcus, pseudomonas and klebsiella are the common responsible agents. Malaria, hepatitis B, hepatitis non-A-non-B and HIV may cause disasters after transfusion. Testing of donors for these diseases is imperative in certain areas.

HIV/AIDS: p. 290.

Management of hypothermia: p. 277.

- **Low body temperature:** Transfusion of several cool blood packs from the blood bank may cause a considerable fall in body temperature. This hypothermia may cause a serious general bleeding tendency. Avoid hypothermia by running the transfusion tube through a cup with warm water (40 degr. C) before it enters the patient.

Coagulation system failure: p. 593.

- **Coagulation problems:** Extensive transfusion of bank blood may cause low platelet counts, dilution of coagulation factors and spontaneous bleeding. Th complication is avoided by alternating bank blood and fresh whole blood.
- **High or low serum potassium:** Old whole blood from the blood bank con tains increased amounts of serum potassium. In patients with major tissue damage, the serum level of potassium is generally increased. After several transfusions of old whole blood (stored for 30 days), hyperkalemia may arise in these trauma patients. After extensive transfusions of packed red blood cells, hypokalemia may rise.
- **Liver injury and citrate intoxication:** Citrate is used as blood bank anti-coagulant. Citrate tends to reduce the serum calcium. The normal liver in a well-circulated patient is capable of regulating the citrate and calcium level. But after liver disease, liver failure or major liver injury, multiple transfusions of bank blood may cause low serum calcium and cardiac arrhythmia. Prevent this complication by injection of 1 g calcium chloride for every 4 units of bank blood.

Points to note – Chapter 19

Hypothermia causes tendency to bleed
- know the types of injury where hypothermia is common: p. 276
- surgery may cause hypothermia: p. 133
- central warming may be life saving in patients with internal bleeding: p. 153

Hypothermia is a common complication of wartime injuries
- know the clinical signs of grave hypothermia: p. 276
- note the circulatory complications during rewarming: p. 277

Injury and surgery may cause malaria crisis with hyperthermia
- note the clinical signs of acute hyperthermia: p. 278 and 288
- know the signs and management of brain edema: p. 301

19 Hypothermia and hyperthermia

Managment of hypothermia

This is hypothermia:
A central body temperature (temperature of rectum or esophagus) below 35 degr.C. In severe hypothermia the central body temperature may be below 30 degr.C. **Notice:** You cannot measure severe central hypothermia with an ordinary medical thermometer – special thermometers with a range from 30 degr.C are mandatory.

Hypothermia is a common complication of major injuries.

Also see p. 131.

Hypothermia is a serious complication: It may cause failure of the respiration, circulation, and coagulation. Volume therapy may have no effect until the temperature is corrected.

Early diagnosis is essential – but is too often missed and preventive measures are not taken in due time.

The risk groups
- Patients rescued after long-time entrapment
- Patients undergoing prolonged evacuation after extensive injuries
- Patients with major burns
- Patients treated with high volumes of cold infusions or transfusions
- Patients operated in cool/airconditioned operating theaters, in particular, extensive laparotomies and thoracotomies
- Small children and old people are generally at risk

Clinical signs in hypothermia

- **34 degr.C:** The patient is conscious, but the cerebral function is slow. Respiratory rate is somewhat decreased. The pulse rate is low, the cardiac output is low and there is risk of cardiac arrhythmia. The urinary output is moderately decreased. There is increasing blood acidosis. There is platelet failure with increased tendency to bleed.
- **32 degr.C:** The patient has shivering that further contributes to the hypoxemia. The articulation is poor though he can say some plain words. He can hardly cooperate. The BP is not measurable. Respiratory rate 8-10/min. There is considerable tissue hypoxemia with acidosis. The tendency to bleed is much increased.
- **30 degr.C:** The patient may still have some bursts of shivering. His eyes are open and may focus on some objects. He cannot speak or cooperate. There is extreme bradycardia, pulse rate may be below 20/min.
- **25 degr.C:** The patient is deeply unconscious. The pupils are dilated and do not contract upon light stimulus. The tendon reflexes are extinguished. The pulse rate is below 20/min, the respiratory rate may be 5/min. There is risk of respiratory or cardiac arrest.There is practically no urinary output. **He may wrongly be evaluated as dead.**

Avoid hyperglycemia!

The response to nutrition is impaired in hypothermia below 34 degr.C. The hepatic function is decreased; the patient is not able to utilize glucose or other nutrients. Parenteral nutrition may cause hyperglycemia.

Management of the hypothermic patient

> **First:** Basic life support – the respiration and cardiac function is most important.
> **Then:** Prevent further cooling.
> **Then:** Start careful warming under continuous monitoring.
> **Handle with care:** There is maximum risk of cardiac complications during rewarming around 30-32 degr.C. Cardiac arrhythmia may be triggered by manipulation of the patient. Take care in all handling of patients at this body temperature.

Respiratory support

- If the patient has at least some respiration, let him breathe on his own.
- Give oxygen via mask to all hypothermic patients.
- Clear airways, consider oral airway.
- Do not intubate unless there is respiratory arrest – there is risk of cardiac arrhythmia during endotracheal intubation.

Cardiac support

- Give sodium bicarbonate 1 mmol/kg body weight to compensate for the acidosis.
- The cardiac function is best monitored by ECG. Avoid "blind" digitalization as it may cause arrhythmia due to cold-induced AV-block.
- Insert bladder catheter and monitor his renal function. Be careful at 30-32 degr. C: If the urinary output is poor, await diuretic therapy until his circulatory state is stable and his central temperature has reached 34 degr.C.
- **Notice:** Ventricular fibrillation at 30-32 degr.C is extremely resistant to electroconversion or drug therapy.

General anesthesia causes peripheral vasodilatation and may thus cause circulatory shock in a hypothermic patient.

Prevent further cooling

- Remove the patient from wind, rain etc. Remove cold wet clothes.
- Wrap the patient in blankets and clothes. Aluminium foil sheets are used if available.
- Avoid exposure to heat – surface rewarming causes increased skin blood flow, circulatory failure and should be avoided.

Start rewarming and close monitoring

Central rewarming is preferable. But be careful: A sudden rise in central temperature may cause cardiac arrhythmia. There are several useful procedures:

- Hypothermia during laparotomies is reduced by pouring warm water into the abdominal cavity.

- Warm infusion through double i.v. cannula causes a slow rise of central temperature.
- Instillation of warm water by peritoneal dialysis, rectal tube, or bladder catheter is useful.
- Conscious hypothermic patients may be rewarmed by warm fluids through a naso-gastric tube or p.o.
- Shivering causes further hypoxemia. Bursts of shivers are managed by i.v. diazepam.
- Stop rewarming at central temperatures of 35 degr.C to avoid later hyperthermia. Then monitor closely: Cold blood from the limbs will enter the central circulation, and may cause another fall in temperature.

Management of hyperthermia

Differentiate between acute hyperthermia and the physiological hyperthermia due to long-time exposure to hot climate.

Acute hyperthermia: A rapid rise in central body temperature above 40 degr.C.

Acute hyperthermia is a common complication in wartime surgery in a hot and moist climate.

Acute hyperthermia is a serious complication: It may cause respiratory, circulatory and mental collapse. The management is aggressive: The central body temperature must be reduced before all his temperature regulation collapses.

The risk groups

- Patients undergoing prolonged evacuations in closed ambulances.
- Victims with injuries of the skull and neck with damage of the temperature-regulating center of the brain stem.
- Exhausted and weak patients with extensive injuries; they have poor capacity for temperature regulation.
- Children and old patients are generally at risk.
- Patients carrying malaria, may develop malarial attacks with hyperthermia as an immediate response to major injury or surgery.

Clinical signs of acute hyperthermia

There is a gradual onset of symptoms with increasing body temperature:

- Increasing PR with risks of cardiac arrhythmias. The cardiac output is low and the urinary output gradually decreasing as a sign of circulatory failure.
- The skin is dry and hot with increased capillary circulation. **Notice:** This may camouflage a circulatory shock and mislead you during diagnosis and triage.

- The respiratory rate is increased. Ventilation is, however, superficial and not effective; there may be tissue hypoxemia and acidosis.
- Bursts of shivers contribute to further hypoxemia.
- Due to brain edema, there is mental confusion that may increase to coma.

Management of acute hyperthermia

- **Start external cooling** to restrict the skin blood flow: Cold wet blankets and clothes, ice and fans are useful.
- **Start central cooling** by double i.v. cold infusions, instillation of cold water into bladder, rectum or by naso-gastric tube. If possible let him breathe cold air.

Malaria crisis: p. 288.

- **In endemic malaria areas:** Give i.v quinine, 500 mg in 20 ml NaCl or chloroquine 0.4 g.
- **Manage shivers** by inj. diazepam i.v. Do not mistake temperature shivers for muscular spasms: Muscular spasms may be due to electrolyte disorders if the hyperthermia has developed after prolonged heat exposure.
- **Brain edema:** In cases of unconsciousness or grave cerebral symptoms, inj.dexamethasone 10 mg i.v is given against brain edema.
- **Oxygen** via mask is given if available.
- **Avoid hypothermia:** Stop active cooling when his central temperature has reached 38 degr.C.

Disorders due to prolonged heat exposure

- **Hypovolemia:** The fluid loss by increased evaporation from the lungs and increased sweating may reach 2000 ml/day (adult) in a hot climate, that is 500-1000 ml above normal. This fluid loss may contribute to hypovolemia after injuries.
- **Hyponatremia:** With increased sweating, sodium is lost. Unless corrected by increased sodium intake, signs of "water intoxication" and hyponatremia may rise: The patient is unresponsive and confused. The peripheral circulation is poor and the urinary output low. There may be spasms of his limb muscles.
- **The management:** High volumes of Ringer or NaCl infusion, salt are added to the diet; additional electrolytes are given after monitoring of serum electrolytes.

Points to note – Chapter 20

Find out which endemic diseases are common in the area where you live and work
- study how those diseases may complicate surgery
- find out how those diseases can be identified before surgery, to prevent complications during surgery

Dysenteries, malabsorption, malnutrition, and starving increase the general risk of complications after surgery
- malnutrition complicates wound healing: p. 581
- malnutrition increases the risk of secondary organ failure: p. 97
- know how to diagnose malnutrition: p. 604

20 Diseases interfering with surgery

Types of anemia

Iron deficiency anemia and surgery
- **Moderate anemia** will seldom cause complications.
- **Chronic anemia:** Surgery may even be done with hemoglobin level as low as 7 g%.
- **Acute, grave anemia:** Increased risk of circulatory failure, wound infections, sepsis and secondary organ failure due to poor tissue oxygenation.

Particular forms of anemia
Sickle cell anemia, thalassemia and anemia due to malaria may all cause serious complications during surgery – even if the anemia is moderate.

Routine
- Test hemoglobin on all patients before primary surgery.
- In some areas blood smear examination is imperative.

Anemia due to iron deficiency

- **Malnutrition and starving** are common causes of iron deficiency, particularly in women of fertile age.
- **Malabsorption** as seen in patients with chronic intestinal infections and tropical sprue (p. 284) is often associated with iron deficiency anemia.
- **Hookworm (ankylostoma) infestation** may cause grave anemia. This helminth is widespread in all tropical and subtropical countries. The clinical signs of hookworm infection are skin itching, bronchitis and moderate abdominal symptoms, but most cases go without clinical symptoms. The diagnosis is made from stool microscopy. The specific therapy consists of bephenium, pyrantel or levamisole.
- **Schistosomiasis** (see below) may cause anemia by blood loss in the urine.

Anemia due to infections

Most infections cause some degree of anemia – the more serious and protracted the infection, the more pronounced is the anemia. Tuberculosis, malaria, leishmaniasis and trypanosomiasis may all cause considerable anemia.

Anemia due to folic acid deficiency

Folic acid is essential to hemoglobin synthesis. As the main dietary sources of folic acid are liver and fresh green vegetables, starvation is a common cause of folate deficiency anemia. Malabsorption may cause folic acid deficiency as seen in patients with chronic enteritis, tropical sprue etc. After hemolytic disorders (sickle cell anemia, malaria crisis) the requirement of folic acid is increased, and deficiency states may develop.

Anemia due to hemoglobin disorders – thalassemia

Surgery and thalassemia
- Increased bleeding due to coagulation disorders
- Cardiac failure
- Transfusion reactions

Thalassemia is an inherited disorder of the synthesis of the protein chain in the hemoglobin molecule. The disease is common in the East Asia, India and Middle East. The anemia associated with thalassemia may be grave with retardation of growth and delayed sexual development. Endocrine disorders may be associated with the disease, particularly diabetes.

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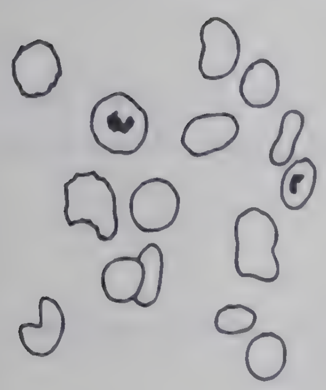

1 **Diagnosis – the typical thalassemia blood smear:** The red blood cells have generally poor color. Note the irregular shape and size of some blood cells.

There is no specific therapy except blood transfusions, preferably with washed packed blood cells. **Notice:** Thalassemia patients should not get iron therapy.

Anemia due to hemoglobin disorders – sickle cell anemia

- **Diagnostic problem:** The sickle cell disorder may imitate other diseases and mislead you!
- **Surgical problem:** A sickle cell crisis with coagulation disorders and blood clotting may arise after any other infection or injury. Surgery may kill the sickle cell patient if you do not take particular precautions!

The hereditary sickle cell disorder, common in the Middle and West Africa, is also seen in the Middle East and India. The disorder is caused by an abnormal hemoglobin molecule creating the abnormal sickle shape of the red blood cells typical of this disease.

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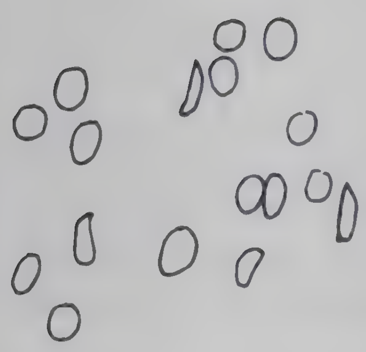


2 **Diagnosis – hemoglobin level and blood smear:** The sickle cell disorder is always associated with grave anemia: A hemoglobin level above 8 g % excludes sickle cell anemia. In endemic areas, a blood smear is imperative before surgery if the hemoglobin level is below 7-8 g %. Note the typical sickle shape of some of the blood cells. Under hypoxemia the sickle shape becomes even more pronounced.

Take a patient's history regarding
- Episodes of jaundice – the sickle cell crisis causes hemolysis and jaundice
- Periods of fever and weakness
- Bone and joint pains
- Periods with acute abdominal pain
- Blood in the urine

- Neurological disorders, hemiplegia etc
- Spontaneous abortions in female patients
- Complications during deliveries in women

Clinical signs
- Short and stunted fingers
- Bone and joint deformation
- Enlarged spleen and heart

Before surgery
- Avoid hypotension: Start aggressive volume therapy with electrolytes and plasma expanders.
- Avoid hypoxemia: Give respiratory support and oxygen.
- Give sodium bicarbonate if the patient is admitted with hypoxemia or hypovolemia.
- Avoid hypothermia: Keep the patient warm.
- Start exchange transfusions if his hemoglobin level is below 6-7 g % : Take venous blood from the patient and exchange step by step with normal fresh red packed blood cells until 1500 ml.

Transfusion reactions are common in sickle cell patients.

In surgery
- Use local anesthesia (infiltration, nerve block or epidural anesthesia) wherever possible – general anesthesia causes more complications.
- Give oxygen via mask. Monitor his circulation closely.
- Avoid excessive blood loss. Replace blood loss immediately with transfusions.
- Do not use tourniquets and do not clamp vessels temporarily: Local hypoxemia may provoke sickle cell crises.

After surgery
Sickle cell patients are a high-risk group regarding secondary organ failure. Monitor respiration and circulation closely.

Malabsorption and vitamin deficiencies

Tropical sprue

Sprue is a state of chronic malabsorption of all nutrients, fat, carbohydrate, protein, vitamins and minerals. The reason is probably a chronic bacterial enteritis in the proximal part of the small gut. The condition is found in all tropical countries, and it is widespread in the East Asia and the Caribbean. Clinical signs: bulky and pale stools, abdominal distention and intermittent abdominal pain, weakness and weight loss.

Sprue and surgery
- Anemia and vitamin deficiencies increase the rate of complications.
- Hypokalemia may cause cardiac symptoms during and after surgery.
- Hypocalcemia may cause cardiac symptoms and spasms after injury and surgery.
- Hypoproteinemia may cause circulatory failure after injury and surgery.
- The sprue patient cannot respond to post-operative high-energy nutrition.

The typical clinical signs give the diagnosis. The specific therapy is also diagnostic: Tetracycline 2 g/day for two weeks will relieve most patients of their symptoms.

Primary lactase deficiency

Many Africans and Asians are lactase deficient: Milk and milk-made diets cause diarrhea – they cannot utilize milk as a basic nutrient. The state is chronic in contrast to secondary lactase deficiency which is common in all patients after acute or chronic enteritis. The disorder may spoil enteral nutrition after surgery – unless recognized.

Vitamin A deficiency

The main sources of vitamin A are liver, dark green vegetables and orange fruits. Vitamin A deficiency is endemic in certain areas as a common result of prolonged malnutrition, enteritis and malabsorption. The main clinical sign of deficiency is corneal ulceration and ultimately blindness. Vitamin A deficiency causes general weakness and increases the rate of complications after surgery. The therapy: injections i.m. of vitamin A 100 000 IU per day for three days, and diets rich in vitamin A.

Vitamin B deficiency

Vitamin B deficiency or "beri-beri" is common in Indonesia and East Asia. The condition may have many clinical manifestations: neurological signs with paresis of the limbs, general edema and circulatory changes with cardiac failure. Particularly in children circulatory disorder with cardiac failure and fluid congestion in the lungs may arise secondary to injury and surgery. The emergency therapy is i.v injection of Benerva or aneurine. Consider venesection of 200 ml blood from a peripheral vein in cases with cardiac complications.

Vitamin D deficiency

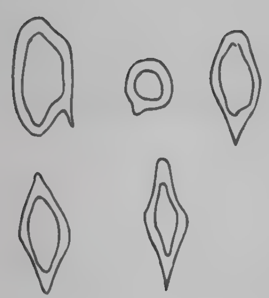
Vitamin D is formed by action of the sun upon the skin. Even in tropical areas vitamin D deficiency may be seen in the big cities. The clinical signs are bone pain and sudden fractures due to poor mineralization of the bones. Pelvic, rib and femur deformities may be seen. Fractures heal slowly and the risk of non-union is increased. Serum calcium is low and cardiac disorders due to hypocalcemia may be seen after trauma and tranfusions. The therapy: vitamin D or cod liver oil together with adequate oral calcium intake.

Schistosomiasis

- **Diagnostic problem:** Urinary tract symptoms may mimic an acute injury.
- **Surgical problem:** Complications of abdominal surgery.

Schistosomiasis (bilharziasis) is a chronic disease of the urinary tract and large gut caused by different strains of the schistosoma parasite. The disease affects 5% of the world's population and is most common in Africa, South America, Thailand, Burma, China, and in the mountainous areas of the Middle East. The parasite lives in water, using snails as intermediate hosts. Certain village populations may be universally infected. The parasite lives and mates inside minor blood vessels in man before they enter the walls of the urinary tract or colon, or follow the bloodstream to cause infection in some other body organ.

3



3 **Diagnosis by identification of schistosoma eggs** in the urine or feces by direct microscopy. The diagnosis may be confirmed by serological tests, rectal biopsy or cystoscopy.

A complex clinical picture – depending upon the stage and site of infection
- **Blood in the urine** – after physical exhaustion, also after major injuries in organs other than the urinary tract.
- **Urinary tract stenosis** may cause partial obstruction and renal failure. Suprapubic catheter or ureter catheter may be indicated.
- **Bladder contracture:** Extensive ulcerations and scarring of the urinary bladder may make bladder surgery difficult.
- **Abdominal complications:** Ulcerations and granuloma of the walls of the rectum, colon and lower ileum may cause intestinal bleeding imitating rupture of the intestine. The infection may cause rupture of intestinal anastomosis, and paralytic ileus after abdominal surgery.
- **Liver failure** and spontaneous bleeding from the gastric mucosa may complicate rehabilitation.

Several drugs are available for specific therapy: Niridazole, metrifonate or praziquantel are all effective against most strains of schistosoma.

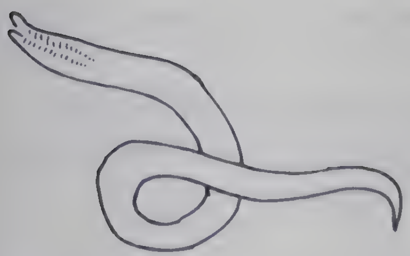
Ascariasis

Be "worm-conscious"!
Ascariasis is common in most Third World countries and the infection may be universal in moist areas.

Ascariasis and surgery

- The worm searches the local gut injuries. They may cause rupture of intestinal sutures/anastomosis – and peritonitis.
- Worms may block naso-gastric tubes and wound tube drains.
- Worms may obstruct the intestinal blood supply, cause necrosis and spontaneous gut perforations after surgery.

Even patients carrying a few worms and patients without earlier clinical symptoms may develop serious worm complications after abdominal injury.



4 The ascaris worm is 10-30 cm long, 2-5 mm broad and whitish-pink in color.

5 Ascaris worms inside the small gut: Ascaris infection may cause inflammation of the gut and formation of adhesions. In extreme cases a bolus of worms may obstruct the small intestine and cause ileus and gut perforation (arrow). In many African countries ascariasis is the most common cause of bile duct obstruction.

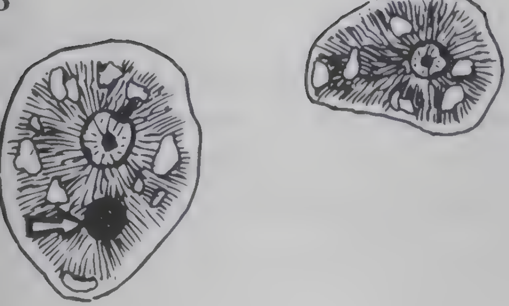
The specific therapy is simple and effective: Piperazine citrate in one single dose of 4 g will cure most cases.

Amebiasis

Amebiasis may cause problems at all stages of wartime surgery – in pre-operative stabilization, at the operating table, and during rehabilitation.

Amebiasis is a worldwide disease found in most tropical, subtropical and temperate areas where the hygienic conditions are poor. The parasite, Entamoeba histolytica, is ingested with contaminated food or water. The disease is most common in patients of 30-50 years of age. The parasite invades the gut wall and causes enteritis with ulcerations mainly in the colon. The diagnosis should be suspected in patients with chronic mild diarrhea.

6



6 Microscopic diagnosis of amebiasis: The diagnosis is confirmed by identification of ameba in the stools, or in smears of mucus from the gut ulcerations. The stool smear is examined by direct microscopy. Repeated smears may be necessary since some stool productions are free from parasites. Note the nucleus of the parasite – compare the size with the red blood cell ingested by the parasite (arrow).

Amebiasis and surgery

- **Poor resistance to injury:** Chronic diarrhea may cause hypovolemia and electrolyte deficiencies.
- **Technical problems:** In advanced amebiasis the entire colon may be deformed by strictures and scarring. The gut wall becomes thin and brittle anc may not take sutures.
- **Post-operative infection:** Abdominal and other extensive injuries may cause a spread of amebas through the gut wall – fistulas, peritonitis and abdo minal abscess may develop.
- **Post-operative bleeding:** Aggressive amebic enteritis with massive bleedir may arise secondary to abdominal injury.
- **Secondary organ failure:** In patients with poor general condition after extensive injuries and surgery, the amebiasis may spread from the intestine and cause liver abscess, lung empyema or cardiac failure.

The specific therapy consists of metronidazole 1500 mg for 2-5 days as tablets or infusion.

Malaria

Diagnostic problem: Plasmodium falciparum – the most potent of the malaria parasites – may cause complex disorders, and imitate other diseases.

Surgical problem: Major injury and surgery in malaria patients may cause extensive failure of the coagulation system.
Precaution: In endemic areas we recommend you to give antimalarial prophylaxis to patients with major injuries throughout the post-operative period.

Blood transfusion: Malaria must be excluded in all blood donors.

Malaria in its different forms is common throughout Central Africa, Asia, the northern parts of South America and parts of Latin America. In endemic areas the patient's history should be taken on admission to the clinic. But only microscopy of thick blood smears and identification of the parasites confirm the diagnosis.

Malaria and surgery

- **Sudden fever and deterioration immediately after injury or surgery.** The fever may mislead you to look for infections. The acute management is cooling by water, ice packs or cold enteral feeding. The attack may develop into cerebral malaria with confusion, spasms, coma and respiratory failure – an emergency treated with prompt i.v infusion of 500 mg quinine and aggressive BLS.

IC and coagulation system failure: . 595.

- **Anemia** due to hemolysis during earlier malarial crisis. Cases with grave anemia may need transfusions before surgery is done.
- **Increased risk of transfusion reactions.** Careful cross-matching reduces the risk. Consider administration of packed washed red blood cells.
- **Coagulation disorders** resembling DIC may arise secondary to major surgery. The treatment consists of transfusion with warm fresh blood. Consider heparin therapy.
- **Acute renal failure** may arise secondary to major surgery.
- **Liver failure** may cause nutritional problems.
- **After splenectomy:** Malarial crisis is common.

The specific antimalarial therapy consists of chloroquine. Sulphadoxie-pyrimethamine is indicated in areas of chloroquine-resistant malaria.

Typhoid fever

Diagnostic problem: Patients without symptoms may carry the infection.

Surgical problem: Weak patients develop abdominal complications.

Risk of cross-infection in the ward: The sources of infection are urine, feces, vomiting and wound discharge from infected patients. Even after specific therapy, the patient may pass salmonella bacteria in his excretions for 3-6 months.

he diazo reaction for typhoid ever diagnosis.
he reagent is made from two solu-ions. Solution A: sulfanilic acid 0.5 , concentrated hydrochloric acid 5 nl and 100 ml water. Solution B: odium nitrite 0.5 g and 100 ml vater.

The procedure: 1 part of solution B s mixed with 40 parts of solution A o form the diazo reagent. 5 ml urine nd 5 ml reagent are mixed with a ew drops of 30% ammonia and haken in a glass tube. A pink or red oloration of the froth implies a ostitive reaction indicating typhoid nfection – all other colors are egative.

Typhoid fever is caused by bacteria of the salmonella group. It is widespread throughout Third World countries. The salmonella bacteria are spread with contaminated water or foodstuffs, particularly milk where the hygienic conditions are poor. The clinical signs are stepwise increasing fever, respiratory symptoms, headache with some mental confusion and enlargement of the spleen. The definite diagnosis is done by blood and stool culture, but these tests take too long. In emergency management better do the diazo reaction which is positive in 90% of all infected cases.

Typhoid and surgery

- **The typical typhoid** fever may erupt secondary to injury and surgery.
- **Abdominal complications:** Ulcerations of the intestines may cause spontaneous perforation of the distal parts of the small gut. Typical is peritonitis and abscess formation in the right lower part of the abdominal cavity. The management is urgent laparotomy with drainage, suture of the perforations or resection-anastomosis.
- **Increased risk of paralytic ileus** after abdominal surgery. The treatment is gastric decompression and chloramphenicol by the gastric tube.

- **Distant infection:** In cases with poor general condition salmonella may spread aggressively and cause lung abscess, arthritis or typhoid fracture infe tion. The management is urgent debridement, drainage and local applicatio of chloramphenicol.

The specific therapy consists of chloramphenicol 500 mg every six hours. In serious cases add metronidazole.

HIV and AIDS

HIV infection is now a major epidemic disease in all parts of the world. In cer tain areas of Central Africa 30% of the population have antibodies against HIV HIV is a virus. Infection occurs when infected body fluids – mainly blood or sperm – from one patient come in contact with open wounds of the recipien Another main reason for infection is sexual intercourse. But HIV may also spread by infected blood during surgery (patient-patient or patient-surgeon). It may spread by blood transfusion. Or by organ transplant (skin grafting). Shortly after entering the bloodstream the virus will penetrate the nucleus of certain population of the lymphocytes, monocytes and brain cells. The virus will multiply inside the cells and cause cell death. After a certain period of time (3-10 years) the immunity will be reduced and certain diseases (Kaposi's sarcoma, Pneumocystis carinii infection, tuberculosis) will appear. The patien has developed AIDS. **Notice:** There is a high rate of complications and death after surgery in AIDS patients – avoid major surgical procedures if possible. HIV-positive patients without AIDS are managed as any other patient.

Prevent spreading HIV during surgery
- Do not use the same instruments on two patients without proper sterilization. Simple boiling or glutaraldehyde solution will kill the virus.
- Exclude HIV in all blood donors. **Notice:** There is always a slight risk of transmitting the virus even if the donor is HIV negative – he may be recently infected and have not developed antibodies yet.
- Do not use skin allografts without knowing if the donor is HIV positive.
- Always use gloves and if possible goggles during surgery, particularly so in high-risk areas.

Section 4

Specific injuries

Points to note – Chapter 21

Beware of airway obstruction
- know the head-tilt and jaw-thrust maneuver in comatose patients: p. 136
- know when and how to do endotracheal intubation: p. 137
- note when and how to do emergency laryngotomy: p. 139

Circulatory collapse for five minutes may cause permanent brain damage
- know the clinical signs of circulatory shock: p. 107
- know the basics of circulatory support: p. 143
- ketamine analgesia increases the blood pressure: p. 149
- know the signs of brain damage and brain death: p. 116 and 301

The skull is a rigid cage – edema and bleeding in the brain cause increased brain pressure – and the brain's blood circulation collapses
- know why edema forms after injury: p. 94
- know how to manage brain edema: p. 302
- know how to evacuate skull hematoma through burr holes: p. 297 and 300

Open skull fractures cause brain infection unless carefully debrided
- know the routines for exploration of skull wounds: p. 296
- do not miss depressed fragments from the inner table of the skull bone: p. 297
- note how tears of the dura are managed: p. 298

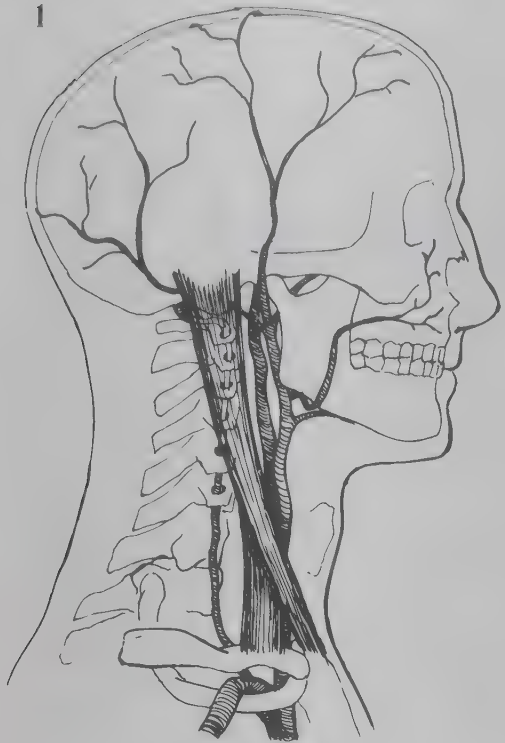
Like all other wounds, the brain wounds must also be debrided
- know how to control bleeding from the brain tissue: p. 298

Suspect associated neck injury in all head cases
- check neurological signs of spinal injury: p. 118
- note how to manage unstable fractures of the neck: p. 310

21 Injury to the head and neck

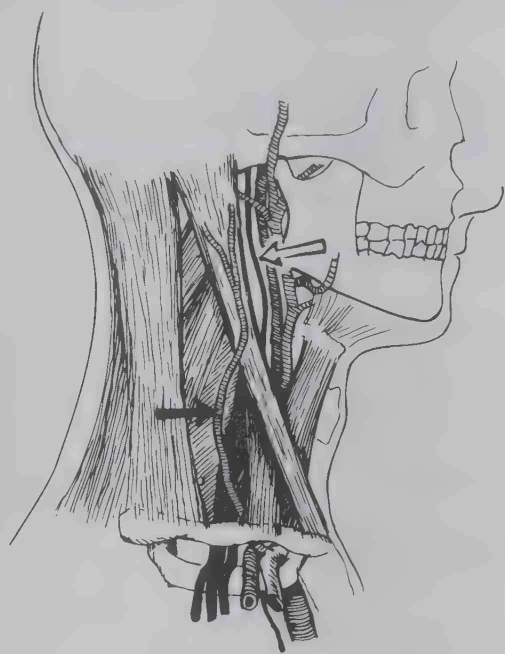
Surgical anatomy

1



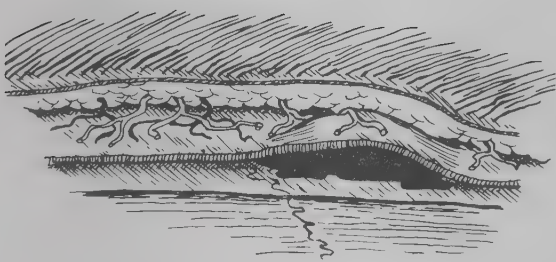
1 The main arteries of the neck: The two internal carotid arteries carry th brain's blood supply. Note that the internal carotid artery starts as low as the level of the thyroid cartilage. Note the superficial, vulnerable position of bo carotid arteries just under the jaw. Note the vertebral artery running throug the transverse vertebral processes.

2



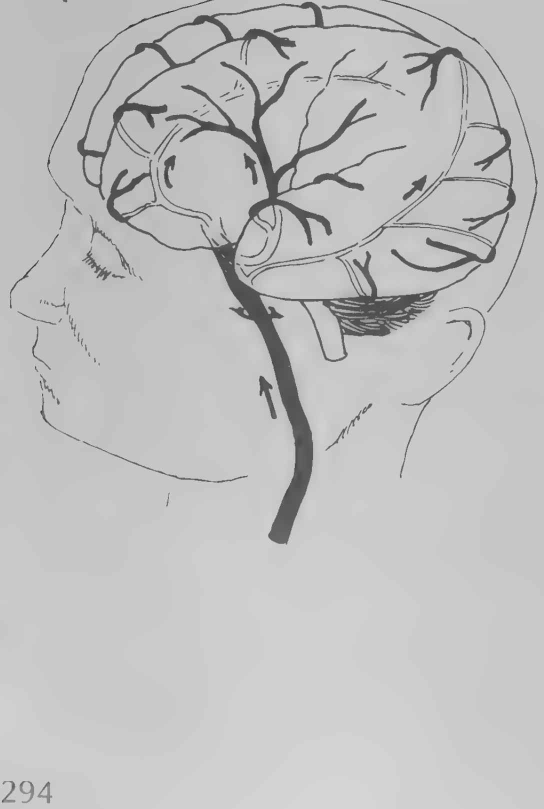
2 The main nerves of the neck Note the level of the brachial nerv plexus – the superior branch is loc ted at the level of the cricoid carti- lage. Just above the clavicular bone the plexus runs rather superficially Blunt and penetrating injuries may damage the plexus at this level. No the vagus nerve (regulating heart a intestinal functions) running close the carotid arteries (white arrow). Also the external jugular vein is illustrated (black arrow); the site fo i.v. cannulation is where the vein rides on the sternomastoid muscle.

3



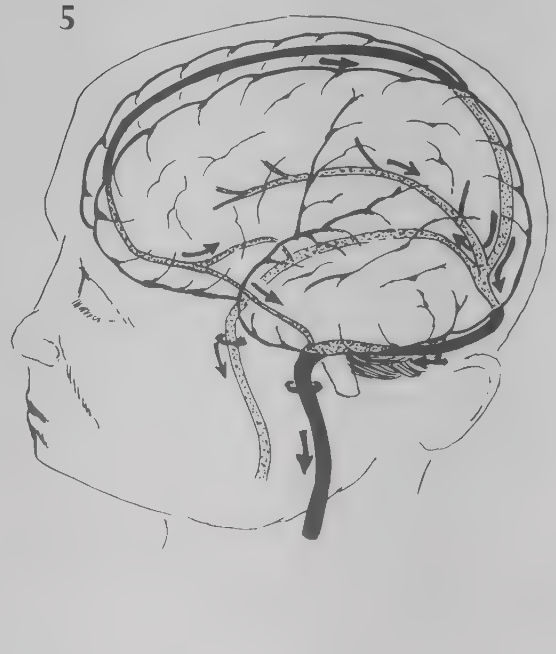
3 The scalp anatomy: Nerves and a rich capillary network run in the subcu taneous tissue. This is where the local anesthesia should be infiltrated to control bleeding during surgery. Under the subcutaneous tissue is the galea – strong, non-elastic fibrous sheet. Hematomas may collect under the galea (as illustrated) or between periosteum and the skull bone.

4



4 The brain and its main arteries: Note the deep course of the anterior a posterior cerebral arteries. Branches of the middle artery run superficially an may be torn by fracture fragments in temporal injuries.

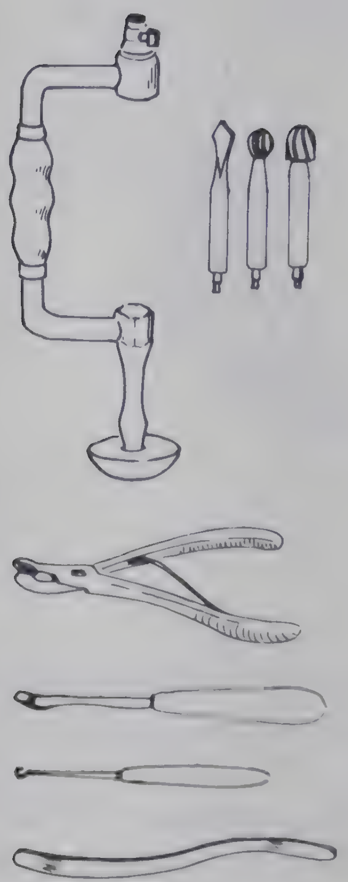
5



5 The venous sinuses are the mai venous drainage of the brain. The smaller cerebral veins empty into th sinuses. The sinuses are located insi the dural sheath, closely attached to the skull bone and are easily torn in fracture injuries. Note the sagittal sinus running exactly in the midline: Take care in the debridement of skul injuries towards the midline not to tear the sinus.

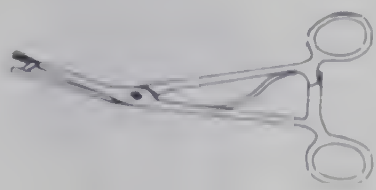
Preparations for surgery. Anesthesia.

6



6 Instruments for skull surgery: The trephine set with drill-brace, perforator and burrs. Bone nibbler, rasp, dura elevator, dura hook and brain spatula. Also fine-caliber scissors, forceps and self-retaining retractors are useful.

7



7 Control bleeding: Ligature with clips is rather expensive but handy under field conditions. Also electrocautery (bipolar) is useful in skull surgery.

Preparations for surgery

- **Isotonic saline:** During surgery the open skull injury is washed with saline (syringe or directly from the infusion set).
- **Suction** is used for debridement of brain tissue. Any suction may be used, a hand or foot pump suction is useful. Suction is done through a fine-caliber plastic tube, a naso-gastric tube cut short will do.
- **The operating field:** Cut and shave the hair well around the injury. The internal injury may be extensive even if the scalp wound is small – better shave a wide field.
- **The operating field:** Fascia grafts for dural tear may be indicated in open skull fractures. Prepare a temporal or a thigh donor area (p. 220).
- **Do not remove skull fracture fragments or deep foreign bodies:** Leave that for the surgeon.
- **Position the patient:** Tilt the table feet downwards to increase the venous drainage. A small pillow under the head eases the access for the surgeon.
- **Anti-edema management:** If the brain is swollen from hematoma and edema it may protrude through an open skull injury. Perform tracheal intubation and SIB ventilate the patient aggressively (hyperventilation) before surgery. Flush infusion of 500 ml mannitol 150 mg/ml may also reduce the brain edema.

IB ventilation: p. 144.

Anesthesia

- **Local anesthesia:** The brain tissue carries no pain receptors. Most skull injuries can thus be managed in local infiltration anesthesia of the skull: Infiltrate anesthetic with adrenaline deep subcutaneously to reduce bleeding from the scalp capillary network.
- **Ketamine anesthesia** is said to increase the brain pressure and contribute to edema in closed skull injuries. In our opinion, this warning is not justified: The positive effects of ketamine in major head injuries (analgesia and improved blood circulation) are greater than the slightly negative effect. Thus we advocate the use of ketamine as anesthetic in closed as well as open skull injuries.

Scalp injury

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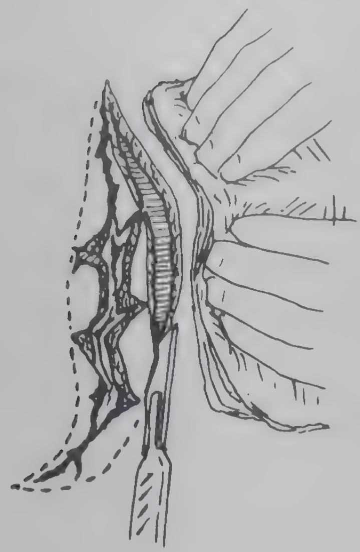

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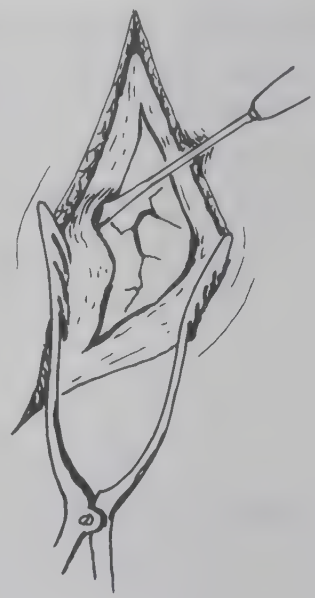

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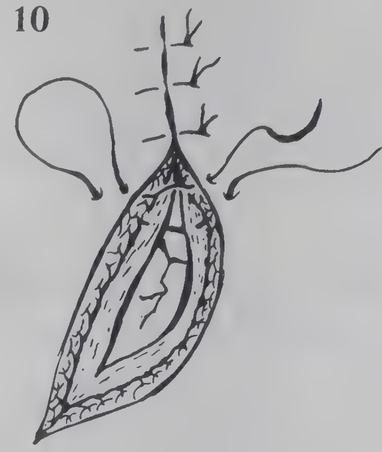

8 Debride the scalp wound: Let the assistant press the scalp just lateral to the incision to control bleeding. Control bleeding by infiltration of a diluted adrenaline-saline at bleeding points, electro-cautery or ligature on small needle. The blood supply to the scalp soft tissues is rich. Small scalp wounds should be closed at the time of injury (delayed suture is not necessary).

9 Explore the skull: Do not hesitate to extend the scalp wound, elevate the galea and periosteum to get a full view of the skull injury. Control the scalp bleeding carefully, otherwise you will be hindered by constant bleeding into the operating field.

10 Closure of scalp wounds: Le mattress sutures include the deep l ers (galea). If the tissue loss makes suture impossible even with lateral relief incisions, apply vaseline gauz and thick gauze padding (spontaneo granulation). Or split-thickness ski graft or rotation flap graft for closu (p. 255).

Open skull injury

- **A common wartime injury with high early mortality.**
- **Do not underestimate a low-energy missile injury:** Even a slightly depressed fracture may cause dural tear and brain damage.
- **High-energy missile injury:** Loss of bone and dura is common.
- **A particular problem:** The high-energy wave from the missile causes bone fragments to penetrate the brain as secondary "missiles". The bone fragments may create pockets of dirt and crushed brain tissue. Debride such pockets carefully to avoid abscess formation.
- **Urgent surgery:** The general advice in any missile skull injury is exploration without delay.
- **Beyond salvation:** Bilateral dilated pupils that do not improve after a few hours in a comatose patient are a sign of major brain injury which normally will not respond to treatment. Operation in such cases is wasted.

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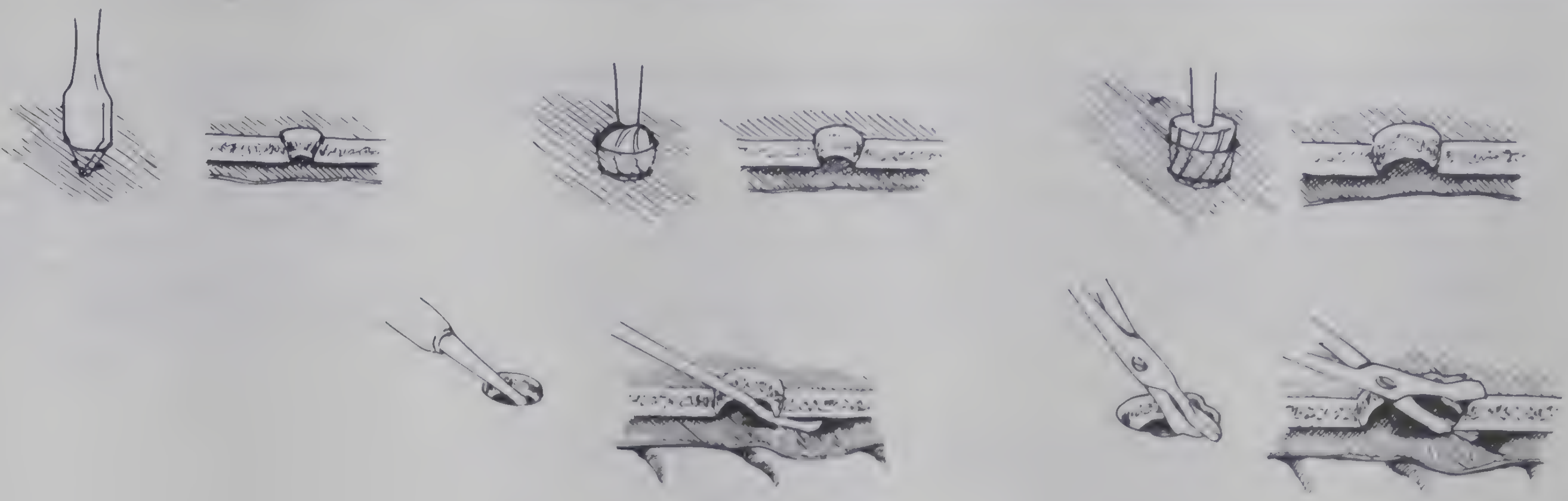

11 Depressed fracture without open brain injury: Even if the outer surface of the skull is just slightly depressed, some fragments may be pressed through the dura into the brain tissue. **Careless manipulation of a depressed fragment may cause serious bleeding:** First drill a hole with the perforator in sound skull bone just lateral to the fracture area until you can see the light blue dura in the hole. Enlarge the hole with the burr. Stop drilling before the burr slips inside! Then lift the dura off the skull bone with the elevator, and nibble the skull bone until you reach the fracture area.

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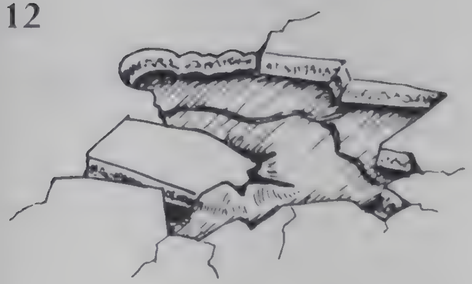

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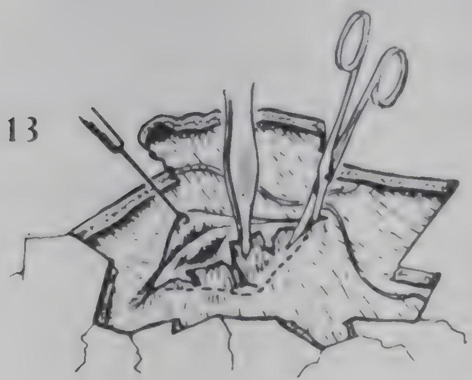

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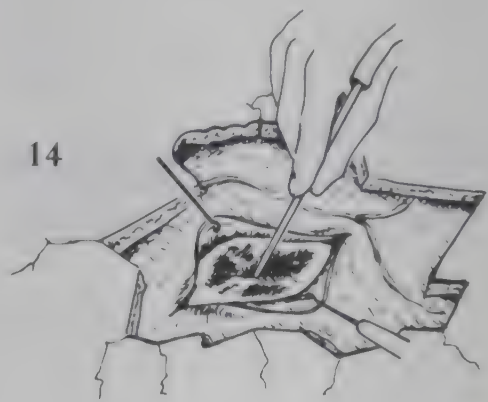

2 **Remove the bone fragments** ne **by one,** freeing them carefully rom their dural attachment. Wash he bone fragments in soap solution, nd keep them in isotonic saline olution while you proceed with the urgery. Remove the depressed fragment last. If the dura under the racture is completely normal, replace the bone fragments and close he wound. If the dura under the racture is undamaged but dark blue r bulging, there is an injury under he dura. Then incise the dura and xplore the brain. If the patient has igns of serious brain damage, the lura should anyway be incised for xploration.

13 Exploration of the brain: A ragged dural tear is debrided. Otherwise incise the dura cross-wise avoiding the dural vessels. Take care if you are close to the venous sinuses (ill 5).

14 Debride the brain tissue: Wash with abundant NaCl and use suction to remove blood clots. Remove bone fragments and dirt from inside the brain, only fragments deeply buried should be left. If you find the missile itself, remove it. If not, do not search for it. Damaged brain tissue is soft and pulpy: Remove it by careful suction and continuous washing with NS. Control every bleeding point (p. 298).

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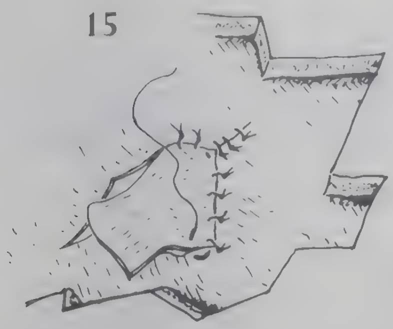

15 Close the dural incision tightly after exploration (silk or Dexon 3-0). Here a graft from the temporal muscle fascia is used for closure.

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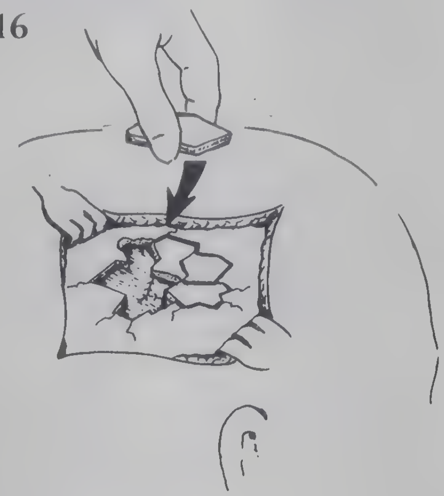

16 Replace the bone fragments onto the skull. Close the skull wou over a soft rubber drain. The drain should not enter the dura.

Control bleeding inside the skull

Increase the venous drainage: Tilt the operating table to keep the head we above the level of the heart. Do not use artery forceps on the delicate brain vessels. They may tear the vessels and increase the bleeding. Depending on th instruments at hand, there are several methods for bleeding control:

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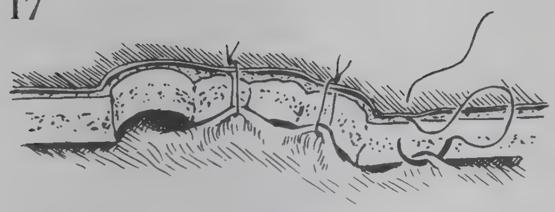

17 Fracture bleeding: Tie up the dura to galea or periosteum with hitch stitches to control oozing from under the skull fracture.

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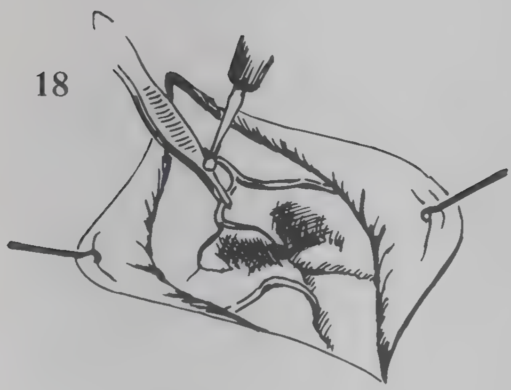

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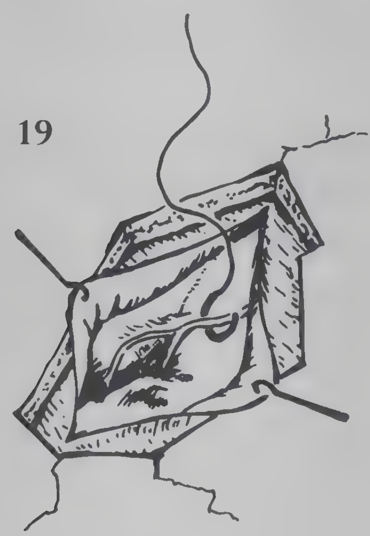

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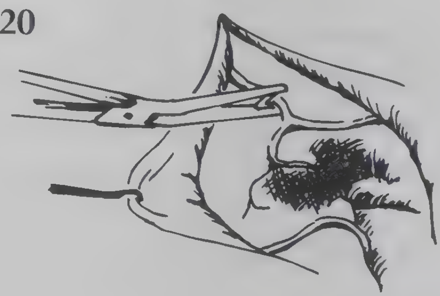

18 Cautery: Grasp the vessel carefully with small forceps, use low-grade cautery current.

19 Ligature: Carefully put a fine suture (silk or Dexon 4-0) under the bleeding vessel and tie it. If the suture cuts the tissue, make two strands of fascia or dura 2x10 mm, and set a ligating U-suture through them.

20 Clips for bleeding control: Vessels of medium size are best controlled with clips.

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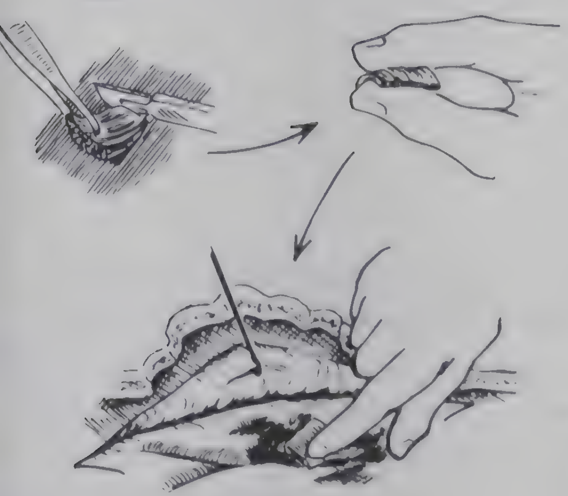

21 **Control by manual pressure:** Apply gentle finger pressure for one minute on a saline-wet gauze pack against the bleeding point.

22 **Muscle patch for bleeding control:** Take a small piece of muscle (eg. from the temporal area) and crush it between your fingers into a thin sheet, about the size of a postage stamp. Apply the muscle patch upon the bleeding area under gentle finger pressure. Within minutes, the bleeding vessel will clot.

Bleeding from deep inside the brain: Pack the bleeding pocket with a warm wet ribbon gauze tampon. Leave it for 10 minutes, then withdraw it stepwise. If it still bleeds from deep inside the brain, use a **two-step procedure:**
- First step: Leave the hemostatic gauze tampon, cover the wound with heavy well-fixed gauze dressing and reoperate within 24 hours.
- Second step: Soak the tampon well with isotonic saline, and remove it. The bleeding would have stopped. Finish the debridement and close the wound as illustrated above.

Bleeding from the venous sinuses: Even major tears in a sinus are controlled by a muscle patch and very gentle digital pressure. The wall of the sinus is thin, and should not be grasped with forceps. The sagittal sinus may be ligated in the frontal area. Ligature of its posterior parts or of the transverse sinuses is usually fatal.

Skull hematoma after closed skull injury

The clinical examination: p. 116.

- **The typical cases:** Entrapment in a bombed house or under vehicles. And blunt injury from stones or wooden pieces accelerated by a blast.
- **Beware of delayed clinical signs:** The skull hematoma may form very slowly, and a symptom-free interval of 4-8 hours between the time of injury and the onset of clinical symptoms is common. Even a delay of several days may be seen.
- **The first clinical signs are discreet, and easily missed:** Look for reduced consciousness and mental changes.
- **Urgent surgery:** Evacuate skull hematomas at an early stage – before they cause increasing brain edema and necrosis.

Drill exploratory burr holes if
- the patient has been unconscious all the time since injury and does not recover.
- he has recovered after the injury – but again he is gradually losing consciousness, becoming restless or complaining of increasing headache.
- there are signs of localized brain damage.

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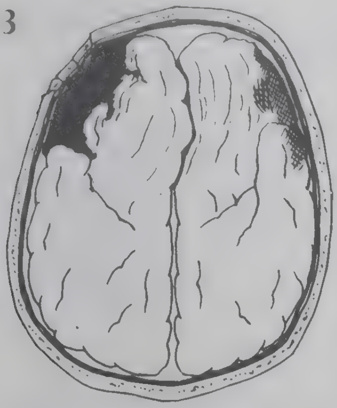
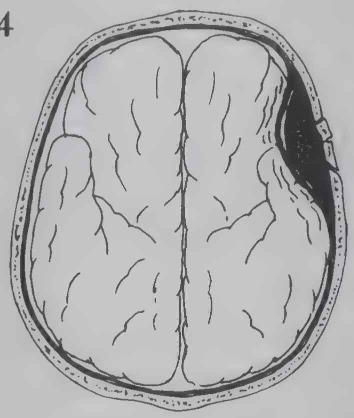


23 Subdural hematomas are common. They are located under the dural sheath, and are formed from a torn brain vessel. **Notice:** The shock wave fro the injury (be it a missile hit or a blunt trauma) may compress the brain again the opposite side of the skull, and form simultaneous hematomas on both sid of the skull.

24



24 Extradural hematomas are rare. They are located between the dural sheath and the skull bone, and are mainly formed from the branch of the middle meningeal artery.

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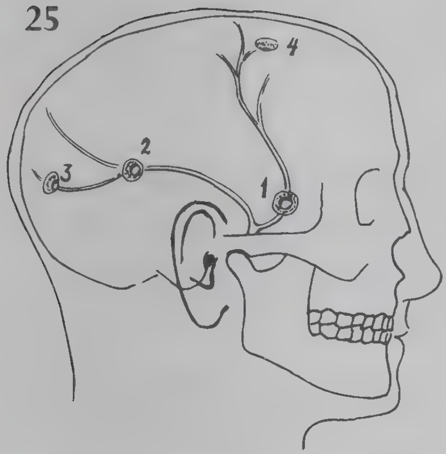

25 Exploration through burr holes is rapid, simple and life saving. The hematoma is usually located in the area where the skull was hit: If there are signs of crush injury, make the first burr hole in that area. If there are no visib signs of injury, the first burr hole (1) is made midway between the ear and the eye on the side with the more dilated pupil. This is the site where most subdural hematomas collect. If the first burr hole is "dry" (no signs of hematoma make the second and third burr holes (2 and 3) in the posterior part of the skull approximately 6 cm from the midline. And a fourth hole (4) in the front area. If all holes are dry, repeat the same procedure on the other side of the skull.

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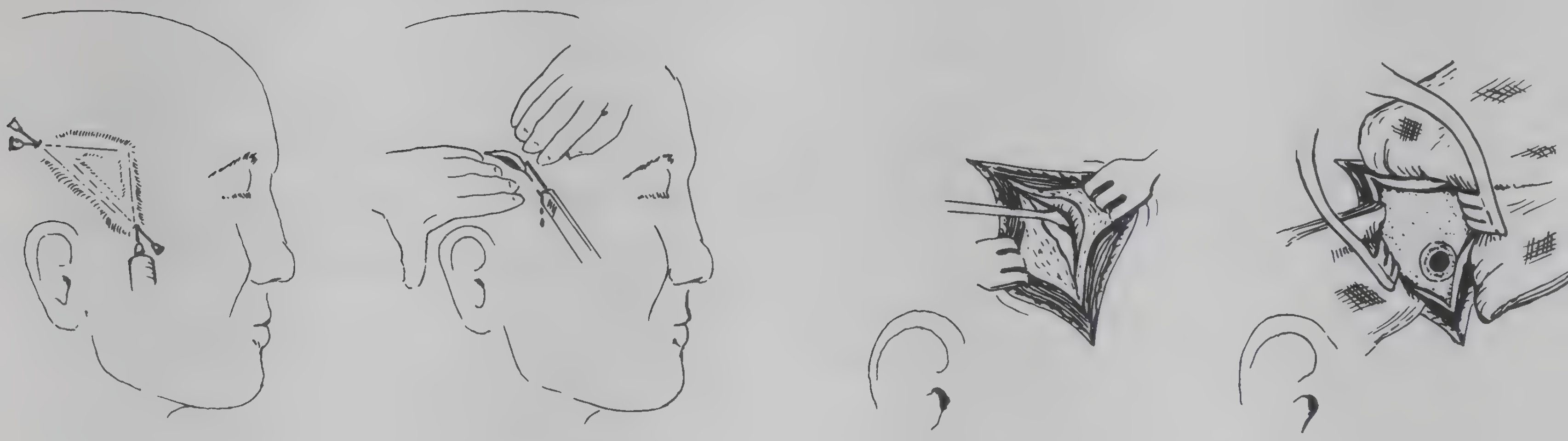


26 Burr holes – the procedure: Infiltrate the area of incision with lidocaine with adrenaline to reduce bleeding. Make a rapid 5-cm-long incision through the skin and galea down to the skull bone in one cut while your assistant applie constant pressure to the wound edges to reduce bleeding. Free the periosteum from the bone, place dry gauze on the wound edges and apply the self-retainin retractor firmly to control bleeding from the scalp. Make the hole with perforator and burr (ill 11).

What do you see in the burr hole?

- **Dark blood is running from the burr hole:** You have found an epidural hematoma. Do not touch the blood clot until you have good access to the area: Nibble some skull bone, then remove the clot by suction and washing with saline. Identify the bleeding points and control them carefully. Open the dura through a cruciate incision to check if there are contusions or pressure damage on the brain under the hematoma. Having explored the brain, leave the dura open without suturing it. Put a small rubber drain from outside the burr hole (not into the skull) through the wound. Close the scalp wound around that drain.
- **The dura is of dark blue color and bulging into the hole:** There is a subdural hematoma. Nibble the skull bone to get sufficient access before you incise the dura and remove the clot. Control bleeding points and debride any brain damage. Close the scalp incision around a soft rubber drain.
- **There is no hematoma:** Maybe you are close to it – search carefully with dura elevator in every direction. If you find the hematoma, extend the hole by nibbling, or make another burr hole. If not, make another exploratory burr hole at the routine sites (ill 25).

If you are sure there is a hematoma inside his skull – do not stop making burr holes even if the patient seems to be dying in your hands: Identification and evacuation of a hematoma may still save him!

Complications of skull surgery

Effective management of complications depends on early diagnosis. Close monitoring after surgery is essential:
- Level of consciousness
- Pupil reaction
- Motor and sensory nerve function
- Temperature, BP and PR

Use the **Head Injury Chart** for exact registration of symptoms and signs. Without written documentation, alterations cannot be identified early. And precise, **minor alterations** may indicate complications – and reoperation.

Head Injury Chart: p. 55.

Brain edema after the injury

Clinical signs of increased brain pressure:
- Changing of consciousness
- Increasing headache
- Vomiting soon after the primary surgery

Management:
- Flush infusion of mannitol (p. 591)
- Consider endotracheal intubation and hyperventilation
- If the patient's condition does not respond: Suspect rebleeding inside his skull. Reoperate without delay

Rebleeding and hematoma formation
Clinical signs:
- Pupil changes in one eye
- Partial paralysis or loss of skin sensation
- Signs of brain edema (see above). Management: Surgical exploration withou delay. Locate and control every bleeding point

Brain infection and abscess formation
Clinical signs of infection:
- Rising temperature
- Signs of increased brain pressure (see above). Management: High doses of potent antibiotics

Clinical signs of abscess:
- There are also signs of localized brain damage (pupil reactions, paresis, rapic ly increasing brain pressure): There is abscess formation in the wound cavity

Management: Explore the wound, evacuate the abscess, wash with abundant saline, debride the necrotic brain tissue that was left over from primary surgery. Close the wound over a soft drain from inside the skull.

Management of hyperthermia: p. 278.

Disturbed body temperature regulation
Body temperature may rise rapidly to well above 40 degr.C without associated brain edema. The hyperthermia soon after a brain injury is caused by injury to the heat-regulating center in his brain, and is not a sign of infection. Cool him with cold water. Consider sedation.

Convulsions
They may be a sign of persisting brain edema.
Management:
- Manage the brain edema (see above)
- Manage the convulsions (else they increase the brain edema): I.v. diazepam 10-50 mg
- In serious cases: Continuous therapy with phenytoin or phenobarbitone for weeks. If the patient seems to recover, gradually reduce the dose

Enteral feeding programs: p. 612.

Gastrostomy for enteral feeding: p. 369.

Problems of nutrition
Optimal nutrition is necessary for the healing of serious head injuries. In comatose or semi-comatose patients, naso-gastric tube feeding is used from the first day after operation. Beware that deeply comatose patients also may have lost the intestinal motility: Start slowly with small doses of carbohydrate solution. If the brain injury is extensive and you expect a prolonged recovery, consider a gastrostomy at the time of primary surgery.

Bedsores and joint stiffness
They will further depress the general condition of a serious head case – they

ehabilitation of head and spinal
ases: p. 638.

are serious complications! The only preventive measures are continuous intensive nursing, passive exercises and joint protection. That program is time consuming and represents too big a load upon a wartime clinic. Mobilize and systematically train his friends and family instead in a complete nursing program.

Management of neck injury

Before any surgical exploration

Is he bleeding into his airways? If so:
- Endotracheal intubation (or laryngotomy)
- Continuous suction of the airways to avoid aspiration
- Then explore the injury and control the bleeding

Before manipulation: Exclude cervical spine fractures
- Clinical examination (p. 117)
- Neurological examination (p. 118)
- X-ray (neck in neutral position)

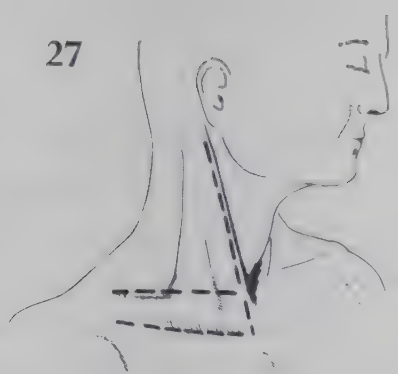
Even the head-tilt airway maneuver may dislocate an unstable spinal fracture.

leck fracture management: p. 314.

General considerations

- **Ketamine** is the anesthetic of choice. As the anatomy is complicated, careful surgery through wide exploratory incisions is important so as not to miss injuries or damage vital structures.
- **Limited debridement:** The soft tissues of the neck have rich blood supply.
- **Open wound management – delayed primary suture.** But tears of the airway cartilage are closed by a one-layer cartilage-skin primary suture.
- **Position on the table:** Extend the neck for better access to the deep structures (cases with unstable fractures – only under skull traction).

27



27 Standard incisions of the neck: The longitudinal incision runs along the anterior border of sternocleidomastoid muscle. The incision gives good access to the main vessels and the esophagus. You may extend the incision along the clavicular bone: The external jugular vein is ligated, the triangular flap elevated and the neck muscles separated by blunt dissection. Do not hesitate to detach the sternomastoid muscle.

Exploration of the subclavian and axillary vessels and the nerve plexus: Excise 5 cm of the clavicle. Work close to the bone, using as a guide your finger upon the subclavian pulse beat to avoid damage to the vessels.

Exploration of the deep structures of the neck: The longitudinal incision is extended up behind the ear. Work with your finger on the carotid pulse beat, split the vascular sheath carefully to explore the carotid vessels.

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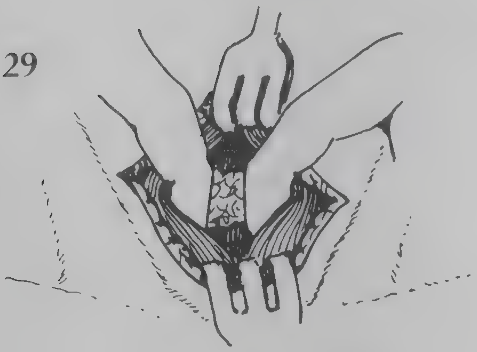

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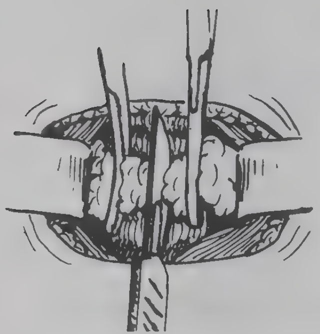

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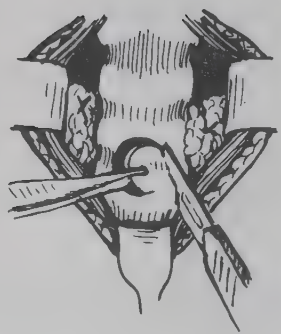

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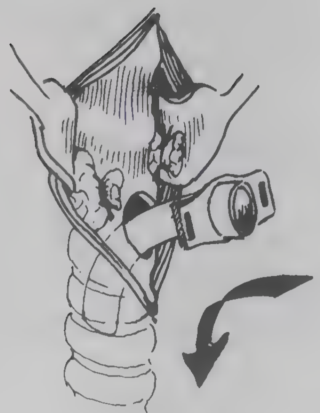

28 **Standard incisions of the neck – the transverse incision:** The trach and the structures in front of the neck may be explored through a transverse skin incision at any level. The underlying muscles are separated by finger dissection. For complete access to the trachea the thyroid gland is separated between ligatures (ill 30).

29 **Injury to the airways – tracheostomy:** Air bubbles in the missile wou mean perforation of the airways. Whether the injury is in the larynx or throu the trachea, a permanent tracheal tube will cause scarring and constriction o the airways. Start the primary surgery making a tracheostomy to control the airways, before you manage the airway tear: With the patient's neck bent bac wards, make a transverse skin incision two fingers above the sternal bone. Separate the muscles with blunt dissection.

30 **Separate the thyroid gland** exactly in the midline between clamps. Ligature on needle through the thyroid.

31 **Cut a hole in the trachea.** Do not involve the first tracheal ring.

32 **Insert the tracheostomy tube** and close the wound. Tie the tube arou his neck.

Now manage the airway injury: If laryngotomy is performed as an emerge cy measure, close it with skin sutures. Any missile tear of the cartilage in the larynx or trachea is debrided and closed with sutures through the cartilage. Cover the cartilaginous sutures with viable soft tissue (muscle-skin flap).

Injury to the brachial plexus: Routine neurological test on admission should reveal injury to the brachial plexus (p. 487). Explore the plexus, control the bleeding, debride the surrounding soft tissues carefully. The nerve injury itself is not debrided but left for secondary exploration/suture 2-3 weeks after the injury.

Injury to the carotid vessels carries high early mortality. Still cases with intimal injury or minor partial tears survive hours of evacuation. The carotids are always explored in high-energy injuries and deep penetrating injuries. The reconstruction follows common procedures. **In emergencies** the internal jugular vein or the carotid artery on one side may be ligated for life-saving rea sons: The brain is well drained through the other side. Some neurological pro blems may follow ligature of a bleeding carotid artery, but in most cases the blood supply from one carotid artery is sufficient.

Injury to the esophagus: Blood aspirated from the stomach in neck injuries may be a sign of missile tear of the esophagus. Explore the missile track through the standard lateral incision (ill 27). Close the esophagus wound with narrow interrupted sutures. Implement enteral feeding for two weeks to avoi fistula formation.

Points to note – Chapter 22

Know the clinical signs of spinal cord injury
- the neurological examination: p. 117
- know some landmarks of sensory dermatomes: p. 685

Some spinal injuries must be handled with extreme care
- identify spinal fractures that may be unstable: p. 308 and 310
- train in evacuation of cases with unstable spinal fractures, including neck fractures: p. 310
- plaster cast may be necessary for safe evacuation: p. 311

Unstable fractures of the neck need skull traction
- wire traction through burr holes is a simple and safe method: p. 315
- note how skull traction is used to reduce displaced fractures: p. 316. And to immobilize fractures: p. 316

Know how to plan a complete rehabilitation program for spinal injuries: p. 628 and 638

22 Injury to the spine

Surgical anatomy. Types of spinal injury

The main questions – regardless of open or closed injury

- **Neurological signs:** Is the cord already damaged?
- **Spinal stability:** Is the cord at risk because of unstable fractures of the spine ?

Principles of management

- **Prevent secondary cord injury:** Manage unstable fractures carefully! Prevent hematoma formation and infection by early debridement, good drainage and careful control of bleeding.
- **Beware during the evacuation:** Most secondary cord injuries happen during field manipulation and evacuation. Careless lifting of the patient may convert an incomplete cord injury to a complete one.
- **Diagnose carefully:** The definitive diagnosis can only be made after days of observation of reflexes and function. Particularly young patients have great capacity to regain function after serious cord injuries provided the injury is not complete.
- **A complete cord injury will never recover.**
- **Major cord injuries:** Concentrate on preventing secondary complications from the airways, the urinary tract, bedsores and joints.

1


1 The close relation between the spine and the cord: Note how small hematomas or slightly displaced fractures will put pressure onto the cord or nerve roots. The management is surgical.

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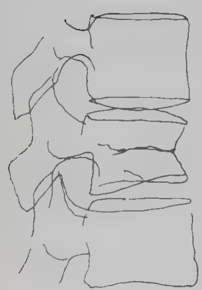

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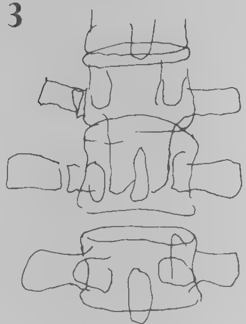

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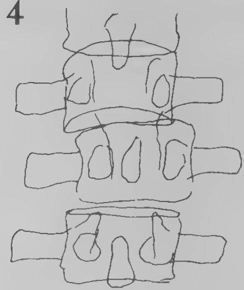

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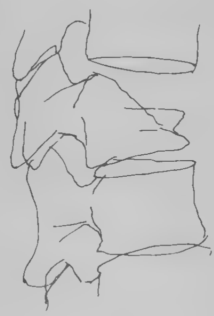

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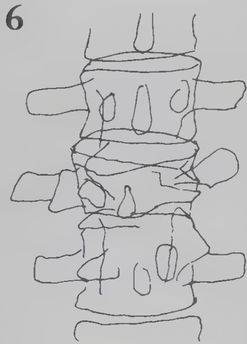


2 X-ray – which fracture is unstable?
Stable: A compression wedge fracture if the loss of vertebral height is less than one third.

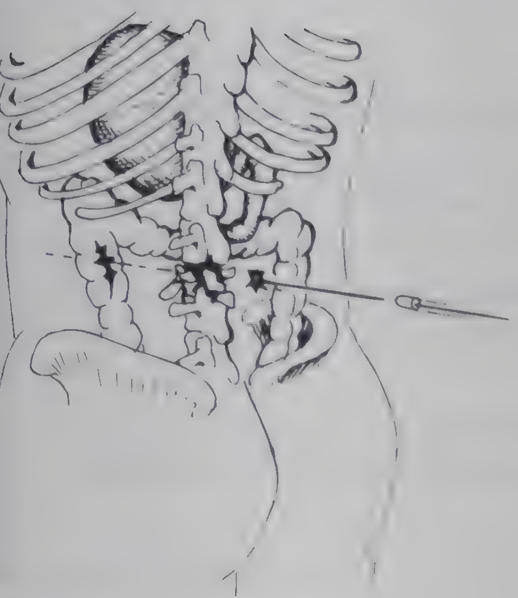
3 Stable: Fractures of transverse processes.

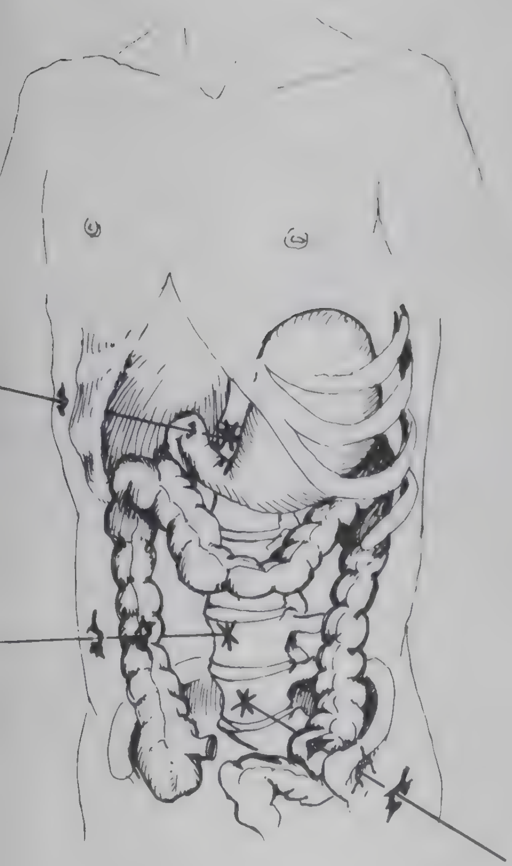
4 Normally unstable: Side-displacements.

5 Unstable: Displacements on X-ray side-view.

6 Uncertain: Compound missile fractures may be stable or unstable. Manage them as if they were unstable.

ne cord ends at the 2nd lumbar rtebra. The "horse tail" below L2 is ldom torn by penetrating missiles.





Types of cord injury

Complete cord injury

Diagnosis: There is a line below which there is no sensory function and motor function.
Management: No surgery. Prevent complications.

Incomplete cord injury

Diagnosis: There is some motor function – even if the sensory function is lost.
Management – open injury: Explore the cord.
Management – blunt injury: Monitor neurological signs every hour for 24 hours. Consider decompressive laminectomy (see p. 317).

Spinal shock

Diagnosis: Scattered neurological signs after a high-energy (blunt or penetrating) injury. The energy shock wave has caused vascular injury and/or edema of the nerve roots and the cord.
Management:

- Neurological examinations every hour for 24 hours.
- If the neurological signs improve, let the patient rest in bed for some days.
- If neurological signs worsen: Methylprednisolone 30mg/kg body weight initially, then 5 mg/kg/hour as infusion for 24 hours. To be effective, the prednisolone therapy should start within eight hours after the injury.
- If he still does not improve, suspect hematoma formation or cord edema compressing the cord → exploration and laminectomy.

7 Do not miss associated injuries: Missile inlet on the back – the abdominal injury is often missed. A posterior abdominal wall injury may be "silent" – consider peritoneal lavage (p. 109). A missed intestinal perforation on the posterior abdominal wall will contaminate the spinal injury.

8 Do not miss associated injuries: Missile inlet through the abdomen – the spinal injury is often missed. Suspect spinal damage when there are signs of posterior wall injury.

Combined abdominal-spinal injury: First manage the abdominal injury, close intestinal tears. Then explore and debride the spinal injury.

Combined limb-spinal injury: Missing the double diagnosis is a common mistake. Limb paralysis indicating cord injury is missed in cases with major limb injuries.

Evacuation

In the fighting area:
- First – triage.
- Then – prepare the evacuation.

Field triage – identify cord injury:
- Motor function – roughly: "Raise your arms! Raise your legs!" It is the tempo of movements that best indicates the cord function: Slow movements – poor function.
- Rectal exploration: Check the function of the anal sphincter muscle.
- Palpate the bladder: Distended bladder – insert bladder catheter before evacuation.
- Sensory function – roughly: Pain response in arms, perineum and legs (pinch the skin).

Field triage – identify spinal injuries that may be unstable:
- All high-energy missile wounds close to the spine.
- All heavy blunt hits towards the cervical or lumbar spine.
- Posterior gap? Turn the patient on his side in one piece (with two assistants). Unwrap clothes and run your finger down the spine: If a "gap" is felt between the vertebrae – assume there is an unstable fracture.

During the examination and evacuation:
Move head, body and lower limbs in one piece. You need at least two assistants during manipulation.

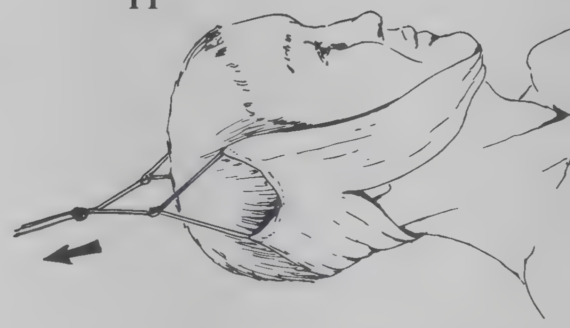
9

9 **Unstable neck fractures** must be supported all the way by manual traction of the head. Do not let the traction go until some other support is applied.

10

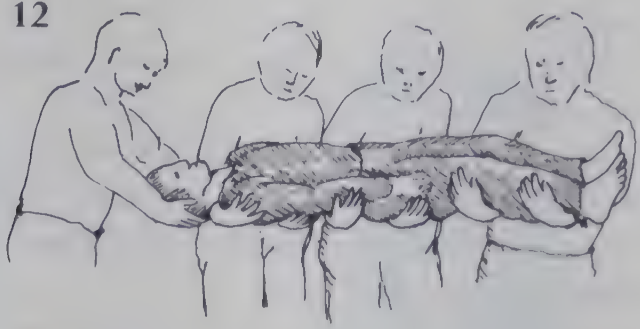
10 **Improvised neck collar:** A broad roll of clothes wrapped around the neck. Wrap some turns of plaster outside the clothes. Or make a plastic collar – cut the top of a plastic bucket and shape it on the fire.

11



11 **Traction upon a cloth/canva halter:** The pull should not exceed kg. Replace this traction within 24 hours by proper skull traction (p. 315) or neck plaster cast (p. 316).

12



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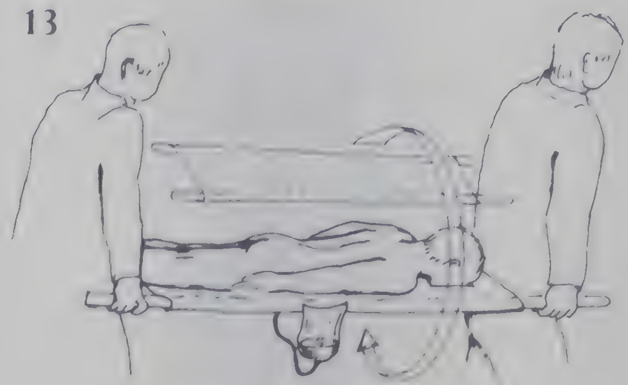
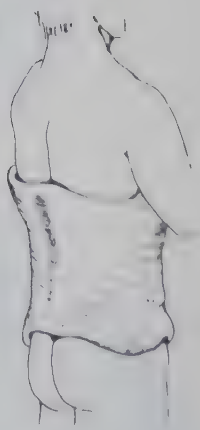


12 Unstable fractures of the lumbar spine: At least four persons must carry the patient.

13 Double stretchers for prolonged evacuations. One stretcher has holes for his face and urine, the other has one hole for stools. Turn the patient every 2-4 hours (change stretcher like a sandwich) to avoid skin pressure sores.

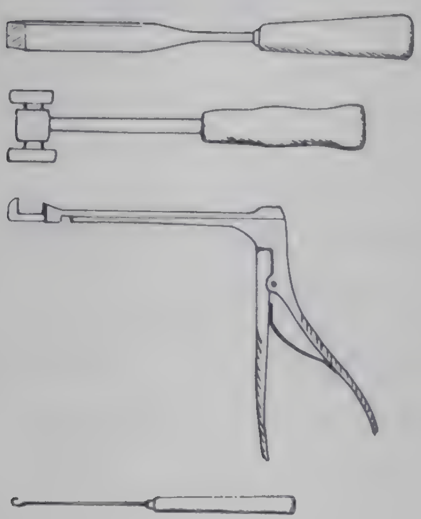
14



14 The lumbar transport plaster cast must be well molded to fit his body exactly. The cast must include his pelvic wings and lower chest to prevent rotation.

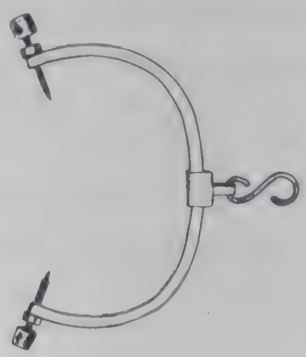
Preparations for surgery. Anesthesia

5



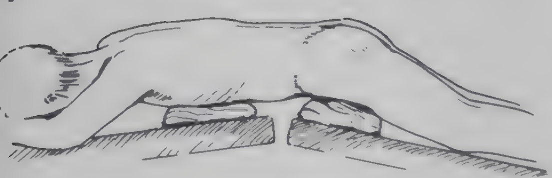
15 Supplement the general surgical set with chisel (straight) and hammer, a punch, two dura hooks, bone nibbler and self-retaining retractors. Bipolar electro-cautery is useful for control of bleeding inside the delicate structures of the spine.

16



16 Skull traction tongs (Gardner-Wells) for traction upon unstable neck fractures. (Any skilled mechanic's workshop can make a good copy.) You may also arrange skull traction with steel wires through burr holes (drill with perforator, dura elevator, dura guide and steel wires: p. 315).

7



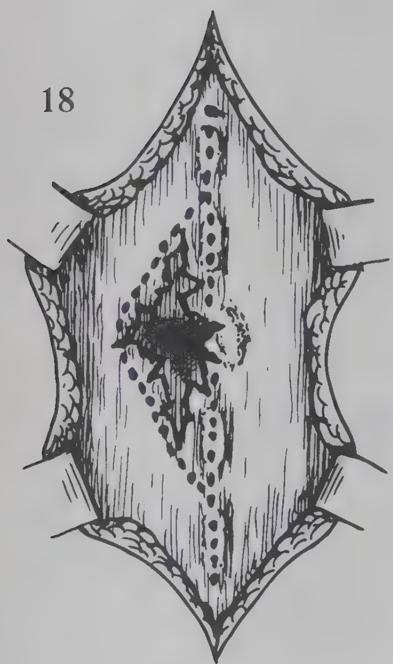
17 Standard position for spinal surgery: Flex the spine slightly over two pillows. For better respiration – do not apply pressure against his abdomen. **Note:** In incomplete cord injury the spine should not be flexed.

Anesthesia

- Extensive injuries with derangement of the spine: general anesthesia with muscle relaxation.
- Most other injuries: intermittent ketamine anesthesia. Or local infiltratior anesthesia combined with low-dose ketamine analgesia.
- Note: Spinal or epidural anesthesia should not be used – dural tears may cause unexpected side effects.
- Adrenaline for bleeding control: During surgery, infiltrate down to the spi processes along the exploratory incision with anesthetic with adrenaline, c dilute adrenaline-saline solution.

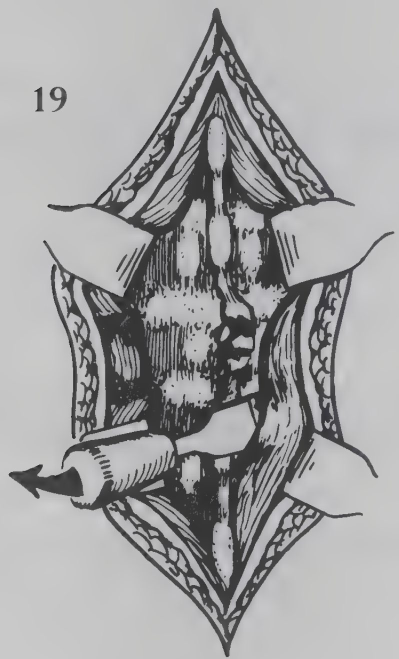
Open spinal injury

18



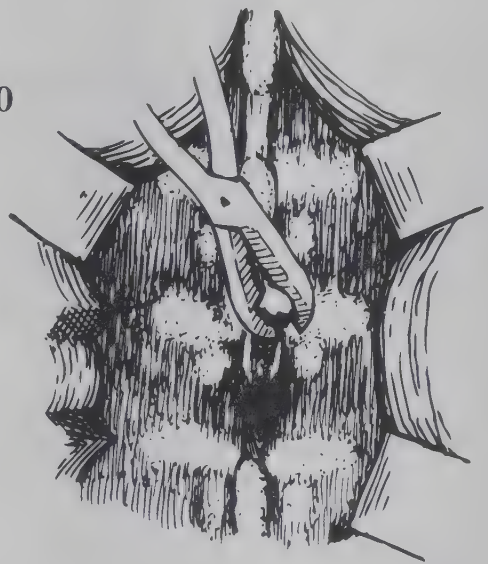
18 The midline incision for spinal exploration and laminectomy: Probe the direction of the wound track with your finger. If you suspect spinal injury, debride without delay: **Either** extend the inlet wound into the standard midline incision, **or** debride the wound track separately. And then make the midline incision to explore and debride the deep parts of the wound track. Extend the midline incision through the fascia down to the spinous processes as illustrated.

19



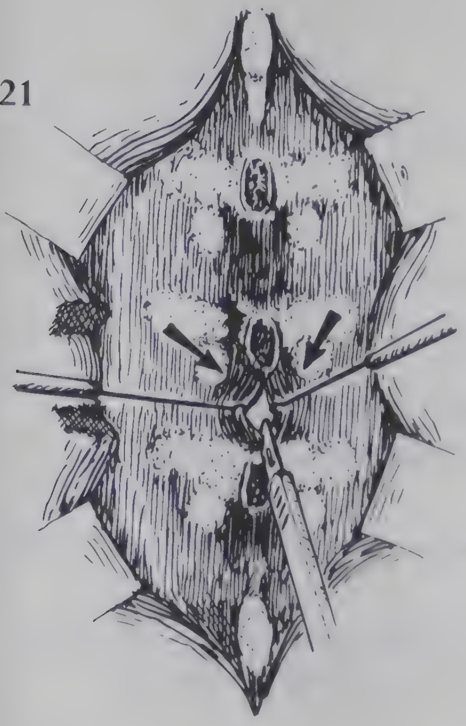
19 Isolate the spinous processes: Strip the long extensor muscles off the spinous processes with the chisel to expose the posterior arch of the injured vertebra. Insert gauze packs on both sides and apply the retractors firmly to control bleeding.

20



20 Laminectomy for exploratio In this case where one vertebra is fractured by the missile, you should explore the dura. To prevent accidental dural tears during surgery, perform laminectomy of the two neighboring vertebrae before you expose the dura: Remove through it neck the fractured spinous process, and the neighboring spinous process with a nibbler.

21



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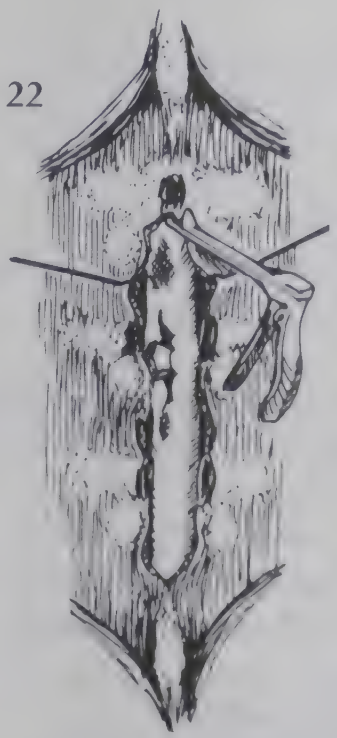


23

Expose the dura: Carefully in-
se the ligament between the ver-
brae exactly in the midline. **Note:**
nmediately outside the dura, in the
pidural space, hematomas may
ollect after open and blunt injuries.
he epidural hematomas may spread
ong the space, cover 3-4 vertebrae
d cause cord compression with
creasing volume. Evacuate the
ematomas completely, control
eeding exactly – and explore the
ira for tears.

22 Complete the laminectomy: Do not remove directly a fragment penetrating the dura – you may damage the cord. First extend the laminectomy, then open the dura to fully expose the fragment: With nibbler and punch the rest of the spinous process is removed together with the posterior arc. Work slowly, small bites only, so as not to damage the underlying dura. Take particular care close to the apophyseal joints (arrows in ill 21) to prevent bleeding. Control bleeding points carefully: Infiltrate the adrenaline solution and pack the field with gauze packs under slight pressure for five minutes.
Dural tear – even small: Open the dura and explore the cord; the internal damage may be extensive. Also nerve roots may protrude through dural tears and become gradually damaged.

23 Open the dura with fine scissors between dura hooks (the cord and nerve roots are just underneath it). Use stay sutures on dural edges. Now remove the fragment carefully. The damaged nerve root cannot be repaired. Inspect the cord and control bleeding points (electro-cautery, tampon or muscle patch – p. 298). If you cannot see the missile, do not search for it. Debride the ragged dural tear and close the dura tightly (silk 4-0). Do not suture dural injuries under tension – better take a fascia graft for closure (p. 298). Then cover the dura by adapting viable muscles or a rotation muscle flap over a soft drain. Be careful that the drain does not press directly upon the dura. The debrided missile track is left open for delayed suture.

After surgery

- Monitor spinal post-operative patients every six hours for two days after surgery: Increasing neurological signs indicate cord edema or hematoma formation (p. 317).
- Patients with laminectomy have a stable spine – no need for traction or plaster. Let them rest in bed with careful exercises for three days. Then mobilize them.
- Unstable spinal missile fractures need traction or plaster casts for stabilization (p. 316).

Spinal fractures

Closed spinal fractures
They are common among mine-injured patients and casualties from heavy city warfare.

Indications for surgical exploration and laminectomy:
- X-rays show unstable fracture with fragments that may damage the cord: urgent surgery.
- The patient has signs of partial cord damage, and his neurological signs increase rapidly: urgent surgery.
- Signs of complete transection of the cord with rapid onset: urgent surgery in lumbar injuries. Surgery at cervical and thoracic level is seldom indicated.
- Moderate neurological signs persist after the period of post-traumatic edema (one week): The reason may be herniation of nerve roots through dural tears, or an epidural hematoma. Consider surgery.

All other closed spinal injuries are managed with traction, plaster cast or simple bed-rest.

Fractures of the cervical spine

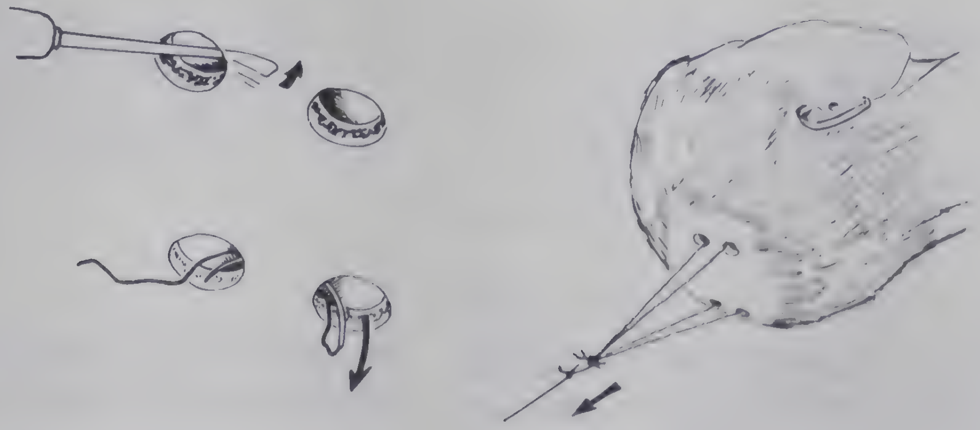
Basic life support: Injuries in the middle and upper cervical spine may produce total motor and sensory loss of both upper and lower limbs. The diaphragm and intercostal muscles may be out of function.
- Observe the respiration: Does he need assisted ventilation?
- Risk of aspiration: Insert naso-gastric tube. Consider endotracheal intubatio

24

24 Skull traction on wire: Cervical spine injury with neurological signs indicate skull traction. **Note:** Continue the manual traction during surgery until the mechanical traction is established. Wire traction through burr holes well tolerated by the patient, the procedure safe and simple. The wartime su geon must get familiar with the method of making burr holes in the skull – th sooner the better. From a nursing point of view wire traction is preferable to the tongs method.

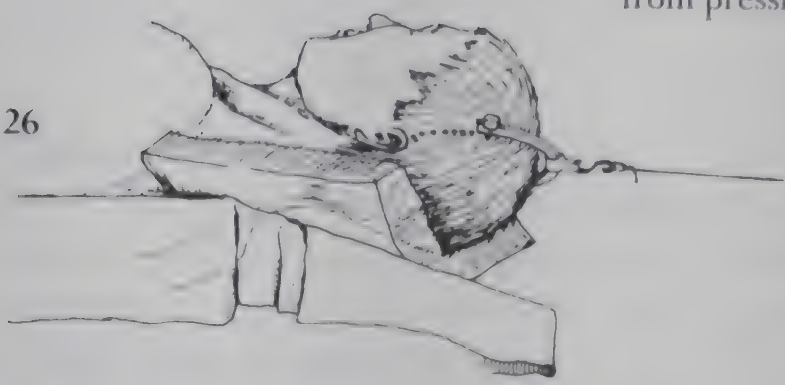
Shave the actual area. The incisions are made 4 cm from the midline and ce tered on a line from the ear to the top of his skull. Under infiltration anesthe (anesthetic with adrenaline) the skull is prepared through a 5-cm incision (p. 300).

25



25 Wire traction – the procedure: Make two burr holes with a 2-cm bone bridge between them. Elevate the dura underneath. Pass a steel wire over a dura guide, or pass a big curved needle (the rounded point forwards) under the bone bridge, tie the wire to the suture and pull the wire through. Tie the two wires together and connect them to the traction equipment. Cut small skin cross-incisions to prevent the wires from pressing on the soft tissues.

26



26 Skull traction with tongs: There are lots of sophisticated tongs for skull traction. The Gardner-Wells tongs are safe and simple. The instrument is equipped with a spring-loaded nipple upon one of the screws. When you tighten the screws, the nipple will protrude. When the nipple protrudes 1 mm from the screw, the tension is correct. Thus you may apply the Gardner-Wells apparatus without making scalp incisions. For locally made copies without the load-nipple – this is the procedure: The insertion is done at the line from 1 cm in front of the ear to the top of the skull. Shave the area, infiltrate anesthetic, and make a 3-4-cm incision (p. 300), just enough to inspect the skull. Apply the tongs exactly symmetrical. Tighten the screws so they penetrate 4 mm into the skull bone. That is, they do not penetrate the inner table of the skull bone and do not reach the dura. Close the incisions.

Skull traction management

- The direction of the traction is strictly neutral – neither cervical flexion nor cervical extension.
- Arrange counter-traction by simply elevating the head end of the bed.
- The skull traction weight (adults): 4-7 kg.
- Monitor the fracture: Increase the weight stepwise, 2 kg every 4-6 hours. Take X-ray side-views to control the effect of each step. The derangement in his spine will gradually become reduced under traction.
- Analgesia prevents muscular spasm and makes the traction more effective.
- Within 24 hours most fractures are brought to a correct position. The traction weights are then gradually reduced under X-ray control.
- Displaced neck fractures more than one week old: Reduction by traction may take some days.
- Displaced neck fractures more than three weeks old: Traction may be without effect – stabilize the fracture in cast or collar.

27

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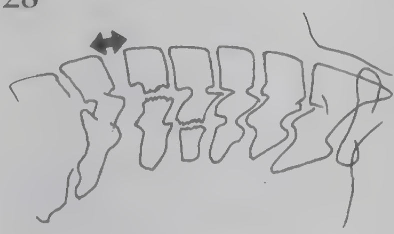

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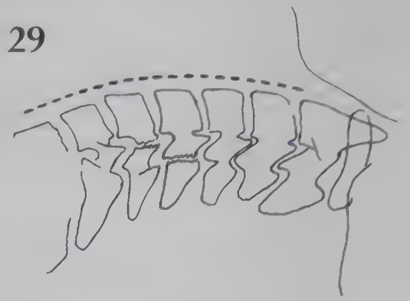


27 Reduction of fractures under traction: Note the displacement of the 6th cervical vertebra, it is hooked on the 5th and 7th (arrows) and must be disengaged.

28 The fragments are disengaged and the position is good except for the gap between the 6th and 7th vertebrae.

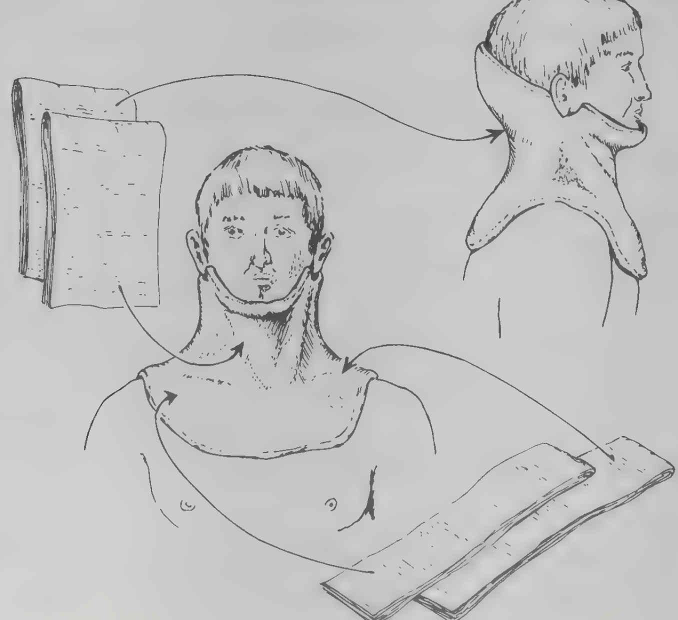
29 The traction weights are gr dually reduced, the gap disappea and the reduction is complete. Th correct curved axis of the cervical spine must be maintained all the w through the reduction procedure. Now leave him in traction for six weeks, gradually reducing the weig during the last weeks. Then apply cervical plaster cast, and remove th traction. Let him wear the plaster cast for another six weeks.

If you do not have X-ray facilities, you should still use skull traction – follow the plan outlined above. Monitor the patient closely with neurologica examinations every six hours. If there is radiating pain or increasing neurolog cal signs, adjust the weights and/or the direction of the traction slightly.

Problems with the skull traction method
- Mental strain on the patient
- Security problem under military pressure
- Inactivation makes him deteriorate: Exercises and high-energy nutrition are essential.
- High load upon the clinic: The patient must be turned in his bed every two hours to avoid pressure sores. At least three persons must turn him – one o them supporting his head so that his neck is not twisted. Train his family an friends in the nursing procedures.

If you are experienced, perform a wire osteosynthesis under local anesthesia when reduction is complete. The advantage is early mobilization.

30



30 Neck plaster cast: The cast must extend the cervical spine – it must have a broad weight-bearing base over the shoulders **and** suppor the jaw and head (occiput). You nee two assistants, one must maintain continuous manual traction, the oth assist with the plastercraft. If the patient is under skull traction, do no remove the traction until the plaster is set. Pad the shoulders, jaw and occiput. Apply two broad plaster slabs – one frontal, one in the back. Apply circular turns and mold the cast well.

Plastercraft: p. 203.

The Trueta plaster method: p. 208.

Primary Trueta plaster management: Extensive neck missile injuries are best managed with neck plaster cast. Apply the cast during the primary surgery under anesthesia. Use the Trueta method with gauze drainage of the debrided wound track. Primary Trueta management allows early mobilization and reduces the nursing load.

Fractures of the thoracic spine

The chest skeleton helps stabilize thoracic fractures, unstable fractures are uncommon. Principles of management:

- Immediate mobilization of moderate injuries.
- Bed-rest for 2-6 weeks with respiratory exercises for extensive injuries.
- Fractures near the lumbar or cervical level are less stable and should be mobilized with care.

Fractures of the lumbar spine and the lower third of the thoracic spine

These fractures may be unstable. Injuries below the 2nd lumbar vertebra have good prognosis, as the spinal cord ends at this level. Principles of management:

- **Stable fractures** are mobilized as soon as possible.
- **Unstable fractures** are exercised in bed for three weeks before a plaster cast is applied. Use the double stretcher principle (ill. 13) to turn the patient every two hours. Arrange small pillows under the lumbar spine to support the natural lumbar flexion.
- **Exploration with laminectomy** is done.

Lumbar plaster cast may be applied for reasons of nursing or evacuation. In unstable fractures the cast should be applied under some traction on shoulders and legs. The cast must include his pelvic wings and lower ribs to prevent rotation of the spine. Pad these areas, and apply four broad plaster slabs – two frontal and two on the back. Then circular plaster and mold well. Within 3-6 months the unstable lumbar fracture is healed. Remove the plaster and start exercises.

Complications of injury and surgery

Hematoma – decompressive laminectomy

Located close to the dura, a hematoma may present increasing back pain and increasing neurological signs within 48 hours after surgery. Even a small hematoma may cause considerable pressure upon the cord and nerve roots. Correct diagnosis in time depends upon exact continuous neurological examination, and written registration of the signs every hour. Monitoring should not stop even if the patient is evacuated during this 48-hour period.

The management of hematoma formation is urgent surgical exploration, evacuation of the hematoma and complete control of bleeding. Obviously the

drainage made during primary surgery was insufficient – improve it. If the reoperation comes late and the nerve roots/cord are swollen, do laminector for decompression.

Wound infection

- **Superficial infection** in a penetrating spinal injury may be the first step towards a tragedy – deep spinal infection with permanent loss of function chronic back pain. Redebride the wound track without delay. Start early intensive antibiotic therapy.
- **Deep infection outside the dural sac:** The signs normally develop after 4-8 days. The infection may run without much fever – the main clinical sig are those of a hematoma: increasing pain and worsening of the neurologica signs. Sudden development of paralysis may be the first sign of infection. T management is urgent exploration with redebridement and decompressive laminectomy. Support the surgery with potent antibiotic therapy.
- **Infection inside the dural sac:** The main sign is meningitis – high fever a stiff and painful neck on flexion. Start aggressive antibiotic therapy but del surgery. If there is no response to the therapy, suspect a deep necrotic focu Re-explore the wound track.

Rehabilitation after spinal injury

Poor post-operative rehabilitation causes more complications than do poor su gery. Teach your medical staff, the patient and his family to regard rehabilita- tion of a major spinal injury as a medical challenge:

Exercises: p. 631-636.

- **Prevent muscular waste:** Make him follow a program of active muscle exercises from the first day! Let him train in bed every single muscle group that is not paralyzed. Encourage him without giving false hopes for the future.

Joint protection during immobiliza- tion: p. 202.

- **Prevent joint stiffness:** Not once a day but repeatedly, the joints of his paralyzed limbs must be moved by an assistant. Make plaster splints for wearing during the night in order to prevent contractures:

31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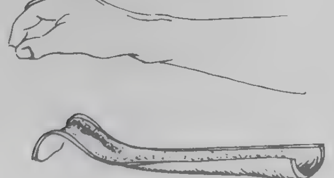


31 Ankle splint to prevent extension contracture.

32 Wrist splint to prevent "wrist drop".

- **Prevent pressure skin sores:** Pressure sores may develop during a single day if the patient is not turned in his bed every two hours – night and day. And if the bed is not well padded with pillows, cotton, etc. Massage the sof tissues to improve the skin blood circulation. Undernourished patients are high-risk cases.
- **A program for nutrition:** Successful prolonged rehabilitation is impossibl without high-energy nutrition. Consider enteral feeding.
- **Prevent urinary bladder contracture and urinary infections:** Unman- aged, a primary partial loss of bladder function may cause urinary infections – and a secondary total loss of bladder function. If you leave an indwelling

urethra catheter for days and weeks, the bladder will soon permanently contract, his bladder function becomes lost – and ultimately he is forced into permanent social isolation. You can prevent this tragedy in two ways:

Automatic bladder: When the bladder is filled up with urine, tell the patient to stroke his penis or the inside of his thigh while he presses his bladder just above the pubic bone. After weeks of this maneuver, the bladder may respond with contraction – an automatic bladder. After his urine is delivered, the automatic bladder must be catheterized for the remaining urine. Continue the catheterization until the remaining urine volume is less than 75 ml. (Teach the patient to catheterize himself.)

Intermittent catheterization: If the patient is not able to develop an automatic bladder after weeks of training, start intermittent self-catheterization. Tell him to use the catheter often, as the bladder should not be allowed to become distended with urine. On the condition he empties his bladder completely (by manual pressure above the pubic bone) during each catheterization, this method will not create urinary infection even if the catheterization is not quite sterile.

Rehabilitation of major spinal injury – the objectives:

- Start the complete rehabilitation program the first day after injury
- Call on his family/friends. Mobilize and instruct them well
- Transfer the patient to his family within two weeks after the injury

Points to note – Chapter 23

Establish free airway immediately
- train in head-tilt and jaw-thrust maneuver: p. 136
- train in endotracheal intubation: p. 137
- know when and how to do emergency laryngotomy: p. 139
- displaced midface fractures must be reduced immediately: p. 322
- know how to evacuate cases with severe face injuries: p. 323

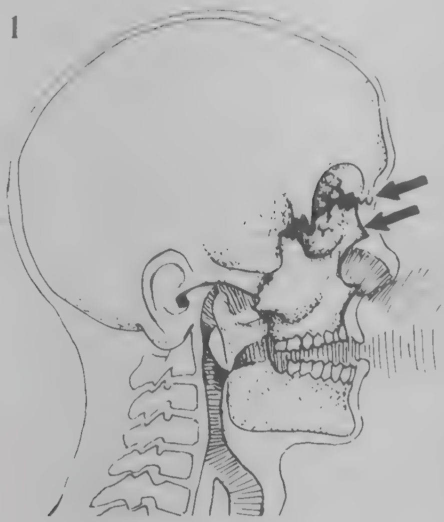
Find out if there is also injury to the skull and brain: p. 115 and 328

At primary surgery, concentrate on the soft tissue injury
- do primary suture of facial wounds: p. 324
- wounds of the cartilage must also be sutured: p. 325
- prevent contractures, do not close wounds at the mouth and eyes under tension: p. 325 and 335

23 Injury to the face

Surgical anatomy

1



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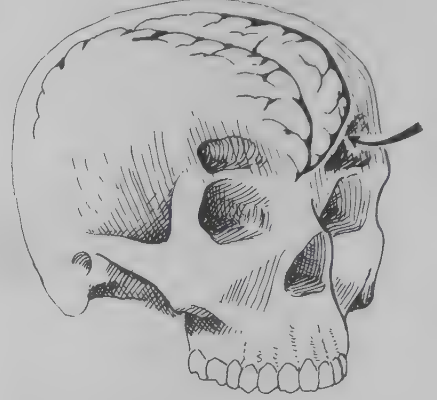
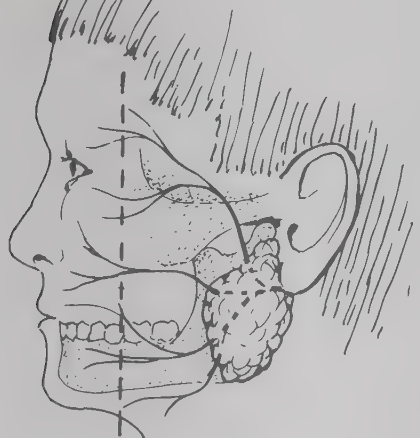


1 Airway obstruction: Displaced midface fractures may occlude the upper airways, the nose as well as the pharynx. Also watch for backwards displacement of the tongue in double-sided lower jaw fractures. Fracture bleeding or aspiration of foreign bodies (teeth, prosthesis fragments) will further contribute to airway obstruction.

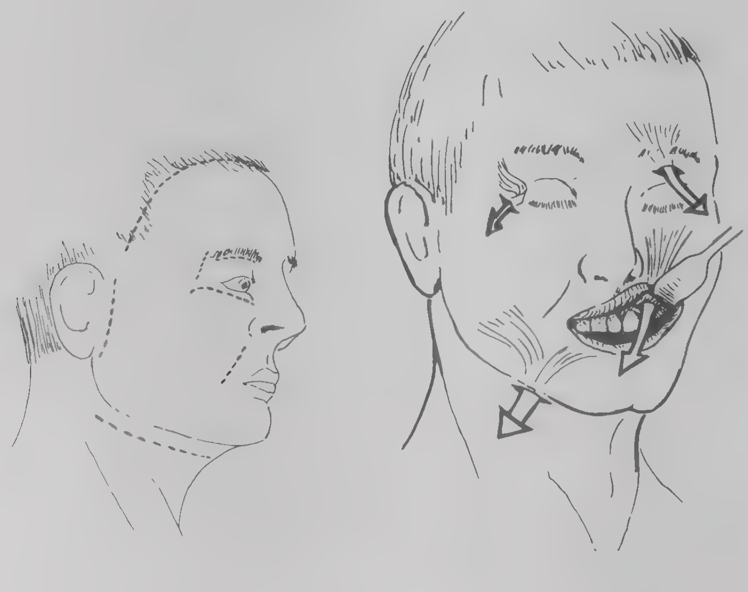
2 Immediate fracture reduction: If you suspect fracture fragments are blocking the airways, make rough reduction in the field. If the fracture is unstable, maintain manual traction by the nose until the clinic.

3 Associated brain damage? N the close relationship between th frontal sinus and the brain. Also h energy fractures of the midface m include fractures of the base of th skull. Fracture hematomas inside skull are usually spontaneously dr ed through the skull base fracture into the pharynx. If not drained, hematomas may collect inside the skull and compress the brain: Exp through frontal burr holes (p. 329

4



4 Facial nerve injury: The nerve branches run through the parotid saliva gland. The nerve innervates the muscles of the face and eyelids. Examine th facial nerve function in all lower face injuries. Take care not to damage the nerve during debridements of the parotid area. Tears of the nerve behind th dotted line should be repaired by secondary nerve suture. In front of that lin one may see spontaneous nerve regeneration.



5 Standard incisions for explo tion and drainage: Note the easy access to the maxillary sinus and fl of the orbit through the mucosa of the mouth. The face structures hav rich blood supply, and proper drai age is important. Also see p. 329.

Evacuation

Basic life support – concentrate on airway management:

Associated brain damage may cause
- the tongue blocking airways
- poor reflexes – aspiration into the airways

The face injury may cause airway obstruction due to
- displaced fractures and hematomas
- bleeding
- foreign bodies

Do not hurry in the forward management
Establish a complete BLS support program inside the fighting area. Continue active BLS all the way during the evacuation.

The airway management

- **In all major injuries:** Head-tilt and jaw-thrust maneuver. Airway suction.
- **Moderate bleeding, awake patient:** Insert an oral airway. Comatose patient: Endotracheal intubation.
- **If intubation is impossible,** do not hesitate to do laryngotomy.
- **Heavy bleeding:** Rough reduction of displaced midface and lower face fractures reduces the bleeding.
- **Heavy bleeding:** Endotracheal intubation. Pack long gauze bands tightly around the tube to control bleeding.
- **Midface fracture bleeding:** A 100-cm thin gauze tampon wet with anesthetic-adrenaline inserted deep into the nasal cavity may reduce the bleeding.
- **The evacuation:** Stable side position, or cut a hole in the stretcher and carry the patient face down. Do not cover the eyes of a confused patient, he may turn desperate.

Preparations for surgery. Anesthesia

Miniplates for fracture fixation?

Unlike in other parts of the body, internal fixation of fractures may be done due to good blood circulation of the facial tissue. Titanium miniplate fixation has reduced the need for elaborate wire jaw fixation of fractures. But the equipment for miniplate reduction is expensive, and seldom available in field surgery. Therefore we discuss the type of surgery you may perform with common orthopedic equipment in the field, for which you need:

- General surgical set, fine-caliber instruments.

- Soft 0.3 or 0.4 mm steel wire (or any soft wire at hand) for fixation of jav
  fractures.
- Gauze bands or ribbon gauze.
- Suction and long, soft suction tubes. Endotracheal intubation set.

Preparations for surgery

Face injuries may bleed briskly during debridement. Manipulation of fractu may induce rebleeding. Soft tissue infiltration of lidocaine-adrenaline or sor dilute adrenaline-saline solution reduces the bleeding. Ribbon gauze soaked with adrenaline solution may be packed into bleeding wound areas for some minutes to control the bleeding.

Anesthesia

Moderate injuries are well managed with local anesthesia. Use a concentrat solution (2% with adrenaline) to reduce the volume infiltrated, high volum will obscure the anatomy. Supplement with low-dose ketamine analgesia fo the same reason. Extensive injuries are best managed with tracheal intubati under general anesthesia.

Soft tissue injury

Extensive injuries – two-step surgery:

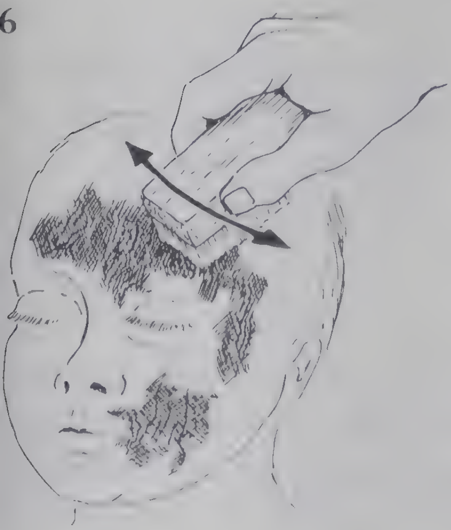
- **Primary surgery:** Face blood circulation is good, tissues have good viability – the debridement is limited. Restore free airways, reconstruct roughly the damaged structures, save all soft tissue possible for secondary reconstructive surgery. Debrided wounds are closed by primary suture if managed within 48 hours.
- **Secondary surgery:** The objective is not cosmetic, but to prevent scar contractures, fistula formation and other complications. Take a second look 2-3 weeks after the primary surgery: Make up the strategy for the reconstructive surgery. Often several operations are necessary.

With alloplastic materials – definitive primary surgery

Inorganic implants (plastic, silicone) are available for reconstruction in majo injuries where there is loss of tissue. Contrary to other regional injuries, primary alloplastic surgery can be done in face injuries due to the rich face blood supply. The advantage is obvious - avoid two-step surgery, reduce the load upon the clinic, early mobilization of the patient. The alloplastic implan are expensive; the method requires skill and sterile facilities: Centralize it to major non-mobile clinics.

For further studies in reconstructive surgery, see textbooks: p. 716.

6



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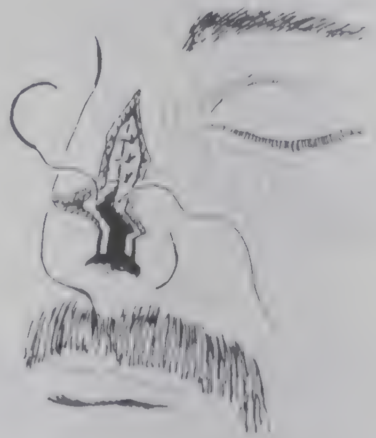


8

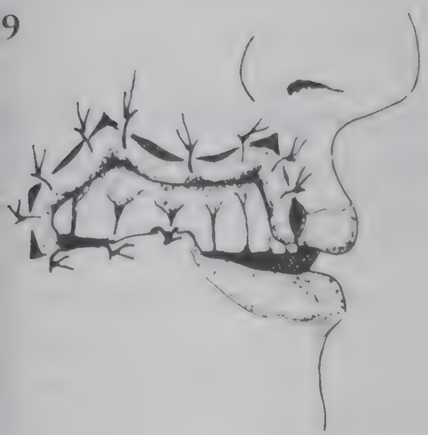
"Tattooing" of the skin: In plosion injuries, small stones and t may be buried deep in the skin l subcutaneous fat. It creates infec n and scarring with dark coloring ttooing). Debride these wounds at time of injury (ketamine anesthe- with firm brushing and sharp ision of all foreign bodies.

7 Deep wounds into the cartilage (nose and eyelids): Take care to identify and suture each layer of the tissues separately and exactly. Here, the interrupted sutures in debrided cartilage.

Wounds at the eye: p. 335.

8 Deep wounds into the salivary glands: The parotid and submandibular ducts are at risk in lower face injuries. If the duct from the glands is damaged, a salivary fistula may form through the skin or into the mouth. Drain these injuries well by primary surgery. Do not try to reconstruct a torn duct at primary surgery, arrange good drainage. A fistula is managed in a secondary operation if it does not close spontaneously within one month.

9



9 Extensive loss of soft tissue: Do not try to close the wound under tension. Debride the defect and suture skin to mucosa of the mouth or nose. Leave the defect for secondary reconstruction. Major soft tissue wounds elsewhere are left open for 5-10 days and then closed by grafting or flap reconstruction.

Open fractures

Examine before surgery

The airways: Backwards displacement of the tongue? Free nasal airway on both sides?

The eye function:
- Tell him to look wide to the sides, up and down – double vision? If so, suspect a fracture of the eye orbit with entrapment of eye muscles.
- Blurring of vision? If so, suspect a penetrating eye injury (the splinter may be tiny).

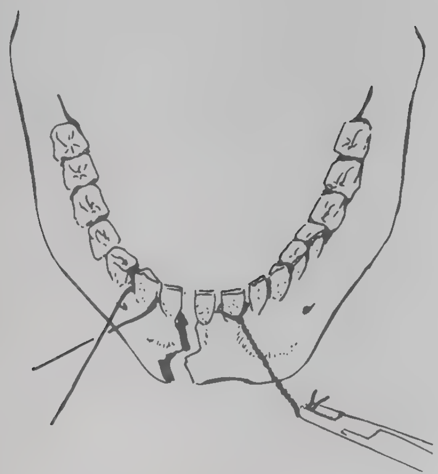
Leaking of brain fluid: Put a urine test strip into his nose and pharynx to examine for glucose. Positive glucose indicates skull base fracture (the cerebro-spinal fluid contains glucose).

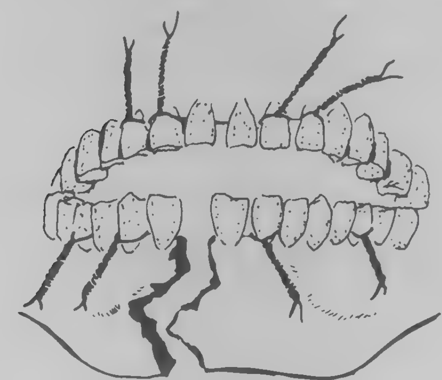
Alignment of the teeth: Fractures of the mandible and maxilla may cause malocclusion. The alignment of the teeth is your best guide for field reduction.

The general procedure

- Make a limited debridement of the soft tissues, particularly of the mucosa
- Reduce the fracture to correct position. Save as many bone fragments as p sible. **Note:** Bone fragments without soft tissue attachment are washed an replaced into the fracture as free bone grafts within 48 hours after the tim of injury.
- Fracture management – alternative 1: Reduce and stabilize fractures of the lower and middle face by interdental wire fixation. Refer the case for mini plate internal fixation if such service is available.
- Fracture management – alternative 2: Stabilize the fracture by packing the area (nose, maxillary or frontal sinus) with saline-wet gauze bands and ext nal slings of elastic bandage. Reoperate within two weeks when the soft tissues have healed and the swelling receded.
- Fracture management – alternative 3: Under sterile conditions and antibio prophylaxis, you may manage facial fractures by primary internal fixation (miniplates) even in high-energy wounds.
- In any case, do not leave the fracture open: Either suture mucosa to the ski to cover the bone ends (ill 9), or raise a soft tissue flap for rotation onto th fracture.
- If you control bleeding well, drains are not necessary. If you use drains, the should be small and soft.

10

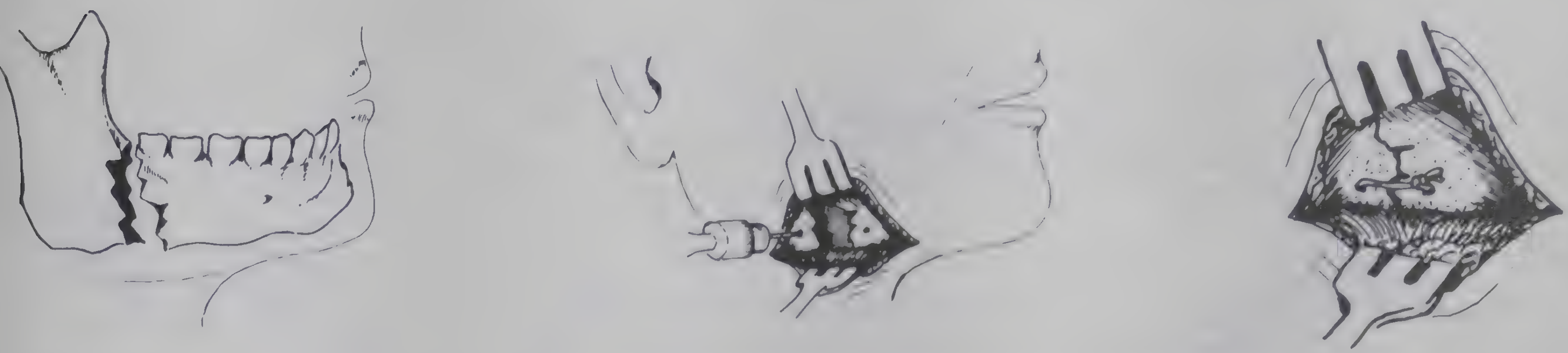




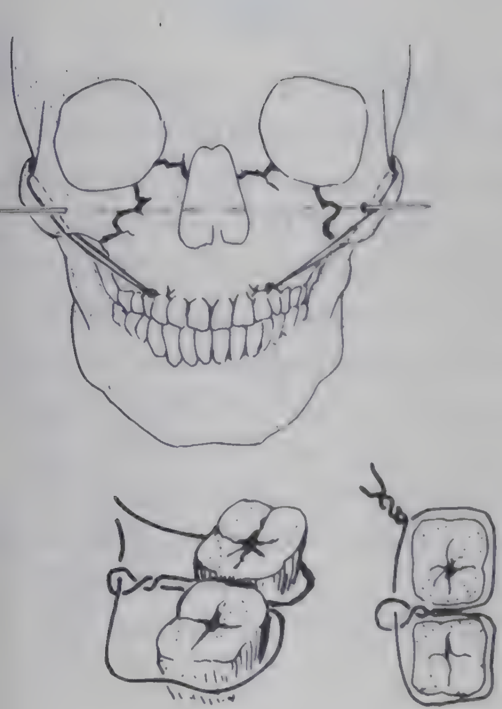
10 Interdental wire fixation of lower jaw fracture: Use his teeth for wire fixation and the opposite non-fractured jaw as splint for the fractured jaw. Use soft steel wire (0.3-0.4 mm). Tie the steel wires around six teeth of the upper jaw a six teeth of the lower jaw. Twist the wires but do not tie them yet.

11

11 Reduce the fracture: When the teeth are well aligned, the fracture is i correct position: Tie the wires – first the lateral ones on both sides, and wor your way towards the midline. Tie them loosely at first, then gradually tighte them. In toothless cases: Use drill-holes through the upper and lower jaw. **Pr caution:** Instruct the patient and his family how to cut the wires if the patie needs to vomit. Instruct the patient to wash and clean his mouth several time day. The dental wire fixation is removed after 6-8 weeks.

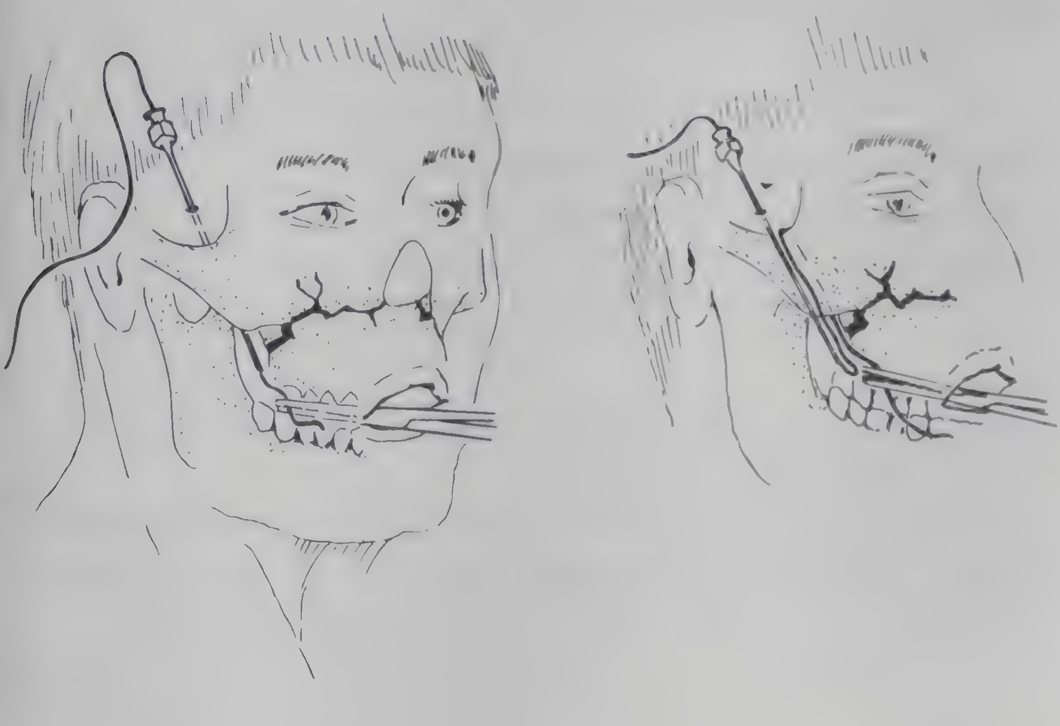


12 Lateral lower jaw fracture: The interdental wire fixation will not stabilize this type of fracture. First step: Debride and provide soft tissue cover for the fracture. Second step: After 1-2 weeks (if the soft tissues are clean), carry out wire fixation through drill-holes. The simplest method is drilling through the upper border of the jaw bone through the mouth. Or a 5-cm incision is made through the skin from the angle of the jaw bone (note the facial nerve). Reduce the fracture and tighten the wire. Support the fixation with a vertical bandage for 3-4 weeks or interdental wire fixation. If available, miniplate fixation is done at the time of primary surgery.



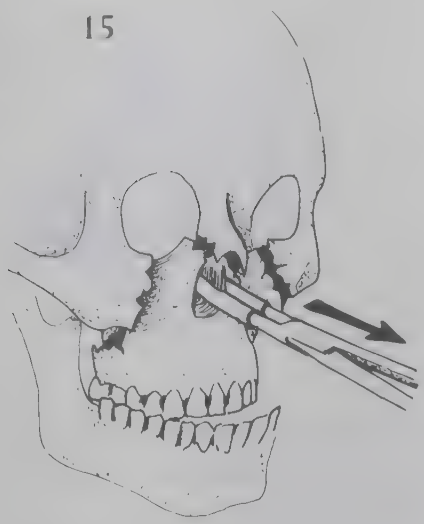
Midface fractures

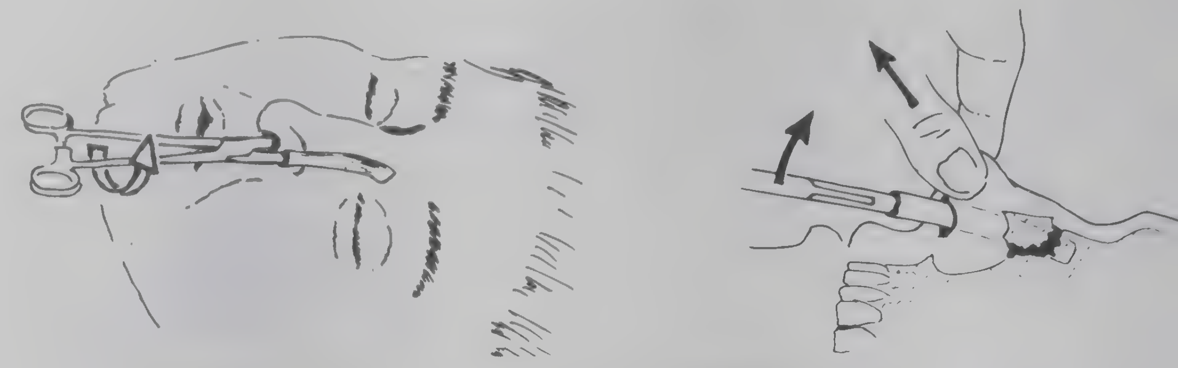
13 Upper jaw fracture – eyelet wiring: Minor and stable fractures of the upper jaw are immobilized with teeth wire fixation between the upper and lower jaws. In major and double-sided fractures, use the zygoma as anchor for upper jaw dental eyelet wires. Consider supplementing the zygoma suspension with interdental wire fixation to the lower jaw (if there is no lower jaw fracture). Fractures with a major central fragment engaging the eye orbit are supported with Kirschner wire drilled from one zygomatic bone to the other as illustrated.



14 Zygoma suspension: The main wire is passed around the zygoma and delivered through a large-bore cannula. If you have miniplates, the upper jaw fracture is managed with open reduction and plate fixation at the time of primary surgery – either through the eyelids or the vestibulum. Also miniplate fixation should be supported with zygoma suspension.

15





15 Nose fractures bleed briskly during debridement and reduction: Use intermittent packing of the nose with adrenaline-saline-wet gauze. The redu tion is done with specially designed forceps (Walsham forceps). But wrappe with gauze or rubber tubes, major artery forceps will do. Grasp the nose sep tum and wings: Mobilize the fragments by traction and careful twisting. Mo the nose into normal configuration. Thereafter the nose is packed on both si with saline-wet gauze bands for one week to stabilize the fracture and contr bleeding.

16

16 Midfacial fractures – the eye orbit: The floor of the orbit and the wa between the orbit and the nose is very thin – even blunt injuries may cause fractures. Soft tissues of the eye (fat, eye muscles, the eye bulb itself) may th herniate through the fracture; the main clinical sign will be double vision. Reduction of even minor fractures of the orbit is important to maintain eye function. Two-step surgery: You may debride and reduce an open fracture through the wound or through the mouth and maxillary sinus. Note the subciliary incision below the eye to control fracture reduction. Replace the eye tissues into the orbit, remodel the floor as best as you can, and pack the maxillary sinus with saline-wet gauze pack for one week. Take care not to elevate the eye too much. Re-explore and reduce the fracture after one week Definitive primary surgery: With alloplastic materials you may reconstruct t eye orbit at the time of primary surgery through a subciliary incision.

Upper face fractures

The signs of associated skull/brain injury

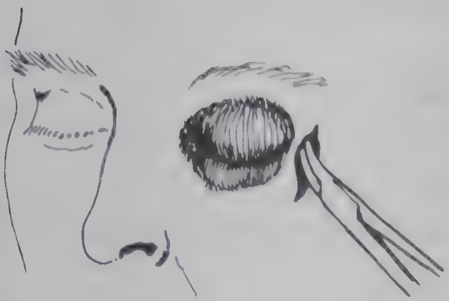
- Neurological signs of brain damage
- Leaking of brain fluid through the fracture
- Retrobulbar hematoma (ill. 18)

Management

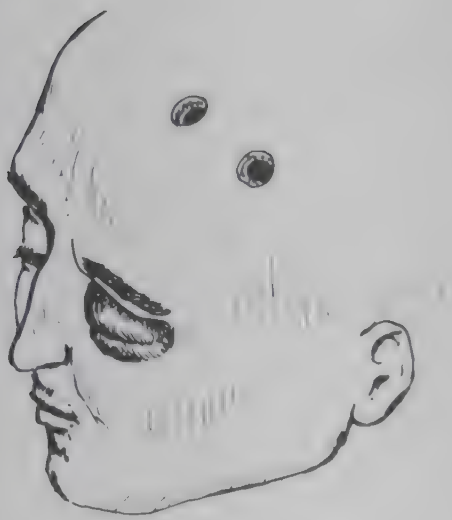
- Risk of infection through the face fracture into the skull: broad-spectrum antibiotics as prophylaxis.
- If the leakage has not stopped after 10 days, explore the skull fracture through frontal burr holes. Repair the dural tear. If you are not able to explore the skull, continue antibiotic treatment for one month.

- Increasing neurological signs: Suspect hematoma formation inside the skull – explore through burr holes without delay.
- High-energy hits: The posterior wall of the frontal sinus may be broken – explore through burr holes at the time of primary surgery.

17 Access to the frontal sinus: Either enter the fracture and the frontal sinus directly through the wound track. Or make an incision just below the eyebrow and chisel into the sinus. The eyebrow incision is also a good way for drainage of the sinus and frontal part of the skull cavity. Compound fractures of the sinus are stabilized by packing the sinus with saline-wet gauze packs.



18 Retrobulbar hematomas: Insert a soft drain through a small lateral incision by careful blunt dissection – keep close to the lateral wall of the orbit.



19 Exploration through burr holes: In high-energy injuries, retrobulbar hematomas often indicate a fractured skull base with brain damage – consider exploration through burr holes. Make two burr holes, nibble the skull until there is sufficient access. Incise the dura cross wise. Retract the frontal brain, control the bleeding and inspect the fracture. Debride the brain, and close dural tears in the fracture area by suture or grafting.

Points to note – Chapter 24

Find out if the injury is penetrating or not
- know the clinical examination in detail: p. 332
- note the suture technique for wounds of cornea and sclera: p. 336

Eyelid injuries should be carefully repaired
- note the anatomical structure of eyelids: p. 334
- close eyelid injuries by primary suture: p. 334
- use local flaps for closure of wounds where there is loss of soft tissue: p. 335

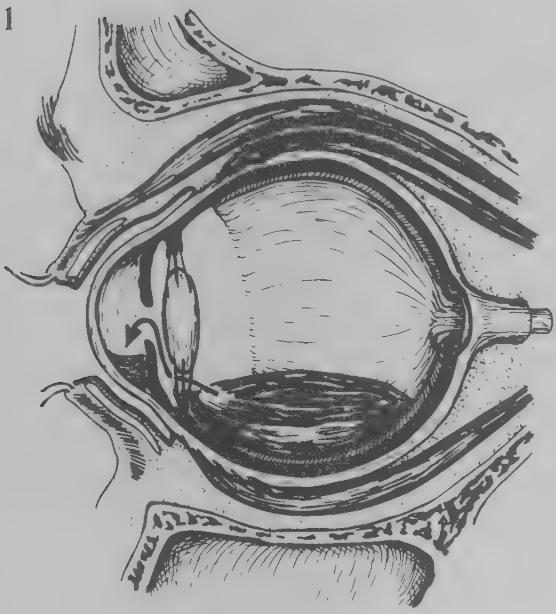
Infection after eye injury
- know the signs of eye bulb infection: p. 337
- know the management of deep infection: p. 337

24 Injury to the eye

Surgical anatomy. The examination

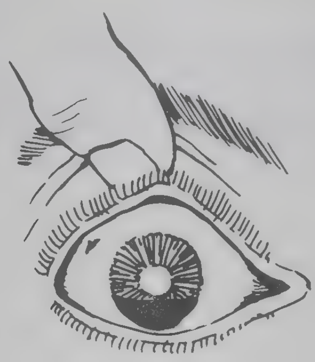
Do not miss the penetrating injuries
- Examine every head and face injury for possible eye injury.
- Examine every eye wound for possible penetrating eye injury.
- Examine every penetrating eye injury for associated skull and brain injury.

1



1 Anatomy of the eye – side-view: Bleeding inside the eye will obscure th vision. Thus, "no vision" does not necessarily mean a "lost eye" – the deep structures may be undamaged hidden behind a blood clot. The illustration shows a hematoma inside the bulb. Note the anterior chamber in front of the iris (arrow) where blood may collect in penetrating eye injuries. More common than hematomas is diffuse bleeding: When an examiner's light through the pupil is seen as a "beam through smoke", it means that blood is dispersed inside the eye.

2



2 The anterior chamber – fronta view: When blood collects in the anterior chamber, this is a penetratin eye injury – look for the inlet wounc Evert the upper eyelid over a pin or forceps. Wounds of conjunctiva may hide a penetrating injury through the sclera into the eye globe. The inlet wounds of high-velocity shrapnel ma be very small, and the penetration almost painless.

The examination

The first clinical examination after the injury is the most important examination. Within a few hours swelling will make further examinations difficult. Th first examination should thus be exact, the results written in the Injury Chart.
- **Anesthesia:** You cannot examine a painful eye properly – apply topical anesthesia (solution tetracaine 1%). Do not apply pressure on the bulb: In penetrating injury, pressure may cause protrusion of the eye content through the wound.
- **Test his vision – four levels:** Can he see strong light, see hand movements, count your fingers, read?
- **Test for double vision:** Double vision may imply hematoma inside the orbit, or a fracture of the orbit with entrapment of eye muscles.
- **Blood inside the eye:** With flashlight, moderate bleeding is seen as "light beam through smoke". Look for blood collection in the anterior chamber.
- **Increased tension of the bulb:** If there is much blood inside the eye, apply gentle fingertip pressure upon the injured eye and compare the tone of that globe with that of the other eye. If the tension undoubtedly is increased, reduce it by tbl. acetazolamide 250 mg every six hours.

- **Wounds of cornea, sclera and conjunctiva:** Even tiny wounds or blood points may hide a serious penetrating injury. If you suspect corneal wounds, apply topical fluorescein upon the cornea: The dye colors corneal lesions yellow-green.

Field management

- **Analgesia and sedation:** The patient with a serious eye injury should not move around. Fear will always accompany loss of vision – consider tranquilizers in addition to i.v. analgesia.
- **Occlusion:** Cover the eye with soft gauze packs. Do not cover both eyes in semi-comatose or confused patients – they turn nervous and restless.
- **Penetrating injury:** Do not extract penetrating shrapnel and foreign bodies before surgery. Do not replace protruded eye content into the eye globe. Apply chloramphenicol eye ointment every three hours. If available, get an ophthalmologist.
- **Bleeding inside the eye:** Let the patient sit or half-sit. Tell him not to move.
- **Napalm/white phosphorus:** When burning particles or small circular wounds are found on the eye bulb, remove particles immediately with any instrument – a plain knife or wooden pin. Do not wash with water or i.v. fluids.

nagement of chemical burns: 572.

Preparations for surgery. Anesthesia

- Fine-caliber instruments: Knife with small blade, fine non-toothed forceps, small needle holder.
- Magnifying glasses are useful.
- Suture materials: The skin – non-absorbable 5-0. Conjunctiva – absorbable 5-0. Cornea and sclera: Silk 7-0 on small curved cutting needle.

Preparations for surgery

- **Routine drugs:** Apply topical chloramphenicol on all eye injuries. In probably penetrating injuries: also give i.v. penicillin 10 mega IU every 8 hours. Never apply corticosteroid ointment on eye injuries.
- **On the operating table:** Put sandbags on each side of his head to reduce head movements and support your wrists – during eye surgery you need a steady hand.
- **Washing during surgery:** Prepare a drip of isotonic saline for rinsing the eye during exploration and surgery. Penetrating injuries: Mix antibiotics with the drip.
- **Priorities:** In combined skull-face-eye injuries the eye surgery can wait. It may be delayed for 3-5 days, provided you give continuous local and systemic antibiotics. This may give you the time necessary for evacuation to an ophthalmologist or experienced surgeon.

Local anesthesia
Even extensive eye injuries may be managed with a three-in-one program:
- Heavy premedication (morphine-diazepam)
- and topical anesthesia (solution tetracaine 1%)
- and infiltration of small volumes of lidocaine 2% with adrenaline.

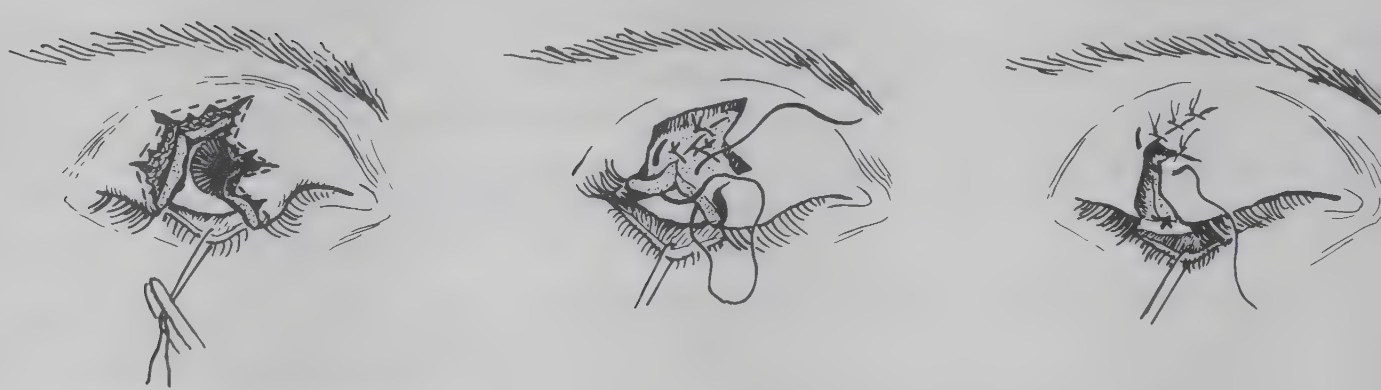
Ketamine – disadvantages: In low doses, ketamine causes rapid eye movements disturbing surgery. Also beware that ketamine increases the pressure inside the eye globe: Use with caution in penetrating eye injuries (risk – protrusion of eye content) and in cases with already increased eye tension (risk – increased bleeding).

Eyelid injury

Primary suture of eye injuries: Due to excellent blood supply and rapid healing, eye injuries are debrided and closed with suture during primary surgery.
Cases late for surgery with considerable swelling of the tissues: Start antibiotics, eye occlusion – and do delayed primary debridement and closure within 3-4 days.

3


3 Eyelid injury without loss of tissue: Limited debridement, 1-2 mm is sufficient. Suture of conjunctiva is not important. Note the eyelid structure: The suture must be accurate, layer by layer to avoid excessive scarring and lid contracture. Suture the fibrous plate with interrupted sutures, absorbable 5-0. A torn muscle (levator palpebrae) should be closed with separate interrupted sutures.

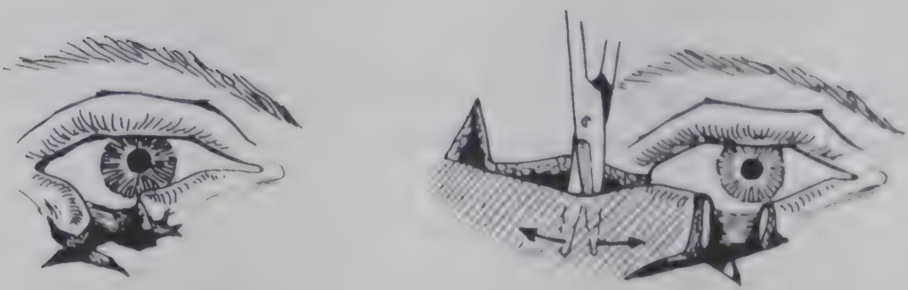
4


4 Eyelid injury with loss of tissue: Study the wound edges carefully to reconstruct the lid structure. Note the single suture in the mucosa-skin line of the upper lid, and the suture for retraction of the lower lid.

5

5 Routine – stay sutures: In every more-than-minor lid injury, apply stay sutures between the hair-rim and eyebrow skin to relieve wound tension.

6



6 Extensive eyelid damage – flap closure: To prevent scar contractures, major superior lid wounds are closed with free skin graft. Inferior lid wounds are closed with a lateral flap.

7 Mobilize the flap by careful dissection in the space between subcutaneous fat and the tarsal plate. Note the stay suture from the lower eyelid to the eyebrow.

8

8 Prevent drying of the eye by tarsorrhaphy: If the eye remains partly open with the cornea exposed to air, it may dry and the cornea becomes permanently damaged. Conjunctiva is the best cover: Close the eye with stay sutures over small plastic tubes (i.v. catheter tubes are fine). In eyelid burns and major corneal injuries, early tarsorrhaphy should be done.

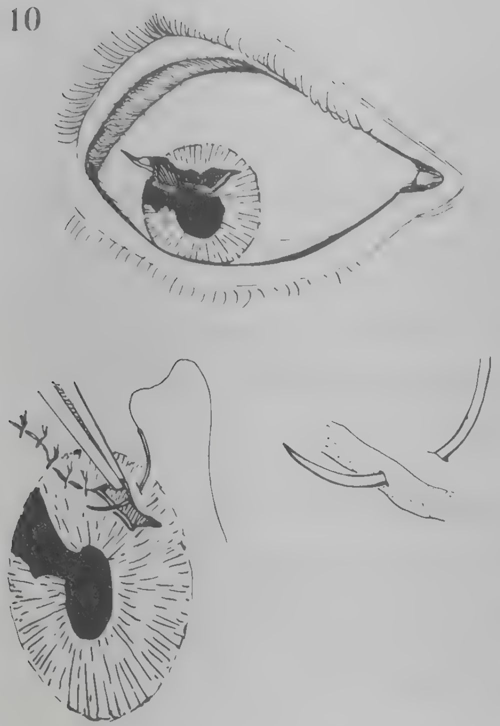
9

9 Extensive damage – refer for secondary reconstruction: To prevent drying of the eye during the evacuation, incise the remnants of the lid in the hair-line, and dissect out conjunctival tissue flaps on both eyelids. Adapt the conjunctival flaps to close the eye. Reconstruction is done within 2-3 weeks.

Penetrating eye injury

Conjunctival wounds close spontaneously if they are small. Major tears should be sutured.

10



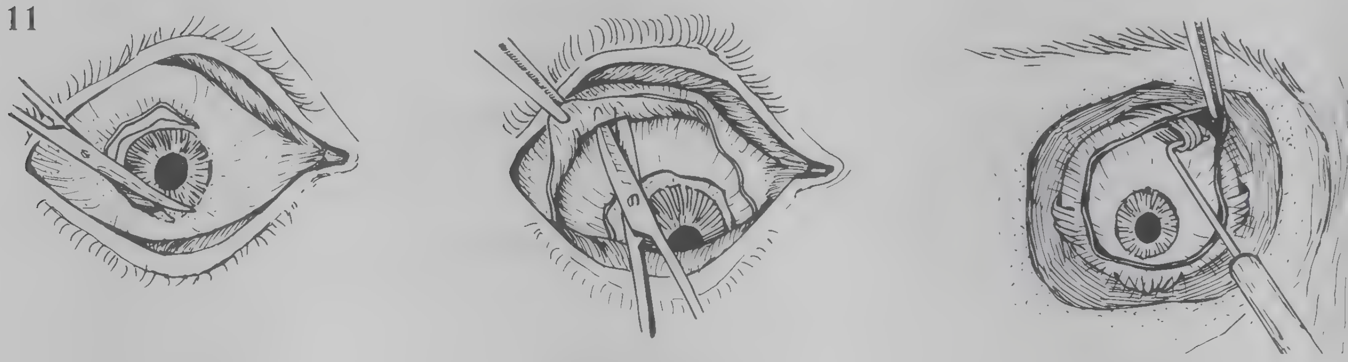
10 Wounds of cornea and sclera are not debrided. Do not manipulate any instruments inside the eye globe: Protruded tissue from inside the eye is cut a level with cornea/sclera. In this case a part of iris is protruding through a corneal tear. Excise it and close the cornea and sclera with close interrupted sutures (non-absorbable monofil 7-0). The cornea is thin (1-2 mm), and the suture should not cross the inner layer of cornea. But if the suture is too super ficial, it will tear the cornea. Do not touch the iris with sutures. Corneal and scleral sutures are removed after one month.

Removal of the eye – enucleation

Hesitate before you remove an eye: Even an eye with light vision only is still useful. In order to discern real blindness after a penetrating eye injury, you have to use a strong light source that may penetrate the blood clot.

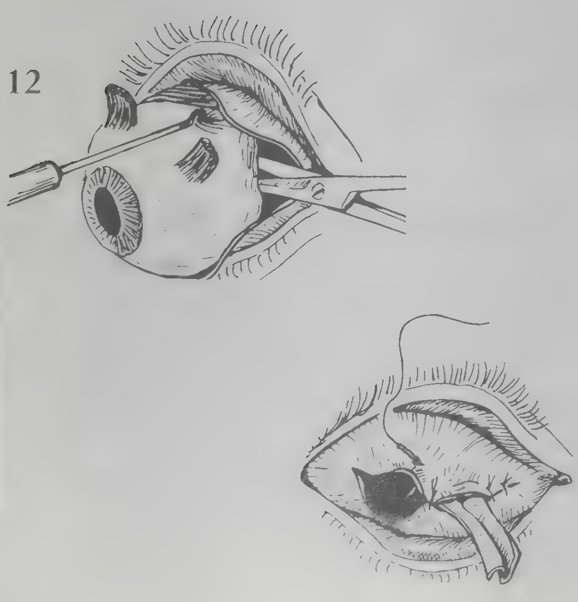
- **Primary enucleation:** A crushed eye globe or extensive derangement is obviously beyond repair. Enucleate at the time of injury to avoid secondary infection.
- **Secondary enucleation:** If you are in doubt, delay your decision until much of the blood is resorbed from inside the eye. Then if there is still no light per ception, that eye should be considered without function – and removed.

11



11 Enucleation – mobilize the eye bulb: Incise the conjunctiva along the limbus and dissect bluntly until you identify the eye muscle attachment upon the globe. Incise the fibrous capsule between each of the muscles, hook the muscles and cut them as far posterior as possible.

12



12 Remove the eye: Retract the bulb forwards under partly blunt, partly sharp dissection along the bulb. Identify and clamp the optic nerve and vessels, and cut them. Remove the eye. Pack the orbit with saline-wet gauze for 10 minutes to control bleeding. Explore the walls of the orbita for fractures. Either insert an eye prosthesis (diameter 15-18 mm, adults) or close the incised capsule and conjunctiva over drain.

Complications of injury and surgery

Monitor for one week after surgery:
- Pain
- Vision
- Signs of rebleeding
- Bulb pressure

Rebleeding

Blood inside the eye is normally absorbed within some days after injury. Bleeding may start again after one week: The eye becomes increasingly painful, the vision reduced, and the bulb pressure increased. The management:
- I.v. analgesia
- Acetazolamide 250 mg p.o. every six hours
- In most cases rebleeding stops spontaneously

Infection

An infected eye reacts with pain on light, the pupil of the infected eye contracts. Also the sclera around the iris becomes increasingly red. You may see tiny white particles in the anterior chamber. The bulb pressure may increase. The management:
- I.v. analgesia
- Topical atropine every eight hours
- I.v. penicillin 10 mega IU every eight hours
- Topical chloramphenicol every hour
- Consider subconjunctival injections of gentamycin 20-40 mg every 24 hours
- Eye occlusion
- Absolute bed-rest

bconjunctival antibiotics: Inject 1 lidocaine 0.5% immediately neath conjunctiva before the antibtic is injected.

Delayed reaction of the other eye

1-2 months after injury/surgery, the other, normal eye may become painful, red and partly lose its vision. This is a sort of immune response to the injury. The condition is rather resistant to treatment and much of his vision may be lost.

The management:
- Analgesia
- Topical steroids
- Eye occlusion

Late effects of metal bodies inside the eye

Even tiny metallic foreign bodies inside the eye may create blurring and gradual loss of vision. This process usually starts 6-12 months after the injury. If an X-ray examination makes you suspect some metal body inside his globe, refer the case to an ophthalmologist for metal body extraction.

Points to note – Chapter 25

Do not miss a penetrating chest injury
- recognize the clinical signs of hemothorax and pneumothorax: p. 106
- associated injuries to the abdomen are common: p. 112

Do not miss blunt injuries
- know the clinical signs of lung contusion: p. 342. And blast wave injury: p. 8
- children are different: p. 262
- know how to manage flail chest: p. 344

Close open wounds of the chest wall immediately: p. 105 and 344

Insert chest tube immediately in all penetrating injuries and serious blunt injuries
- four out of five penetrating injuries are well managed with chest tube withou further surgery. Study the procedure in detail: p. 142
- early chest tube insertion is even more important in children and old people: p. 260 and 264

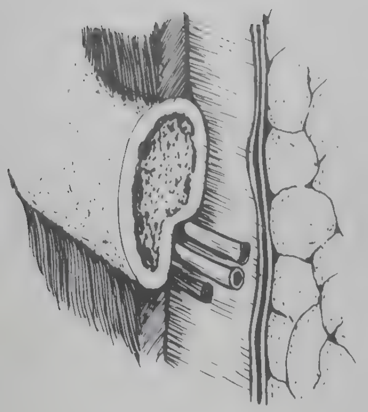
Analgesia supports the breathing
- know the side effects of pain: p. 98
- know the i.v. doses and side effects of pentazocine, morphine, and ketamine: p. 151
- pleural analgesia is safe and simple: p. 674

Know the reasons to do early thoracotomy after chest injury: p. 345

25 Injury to the chest

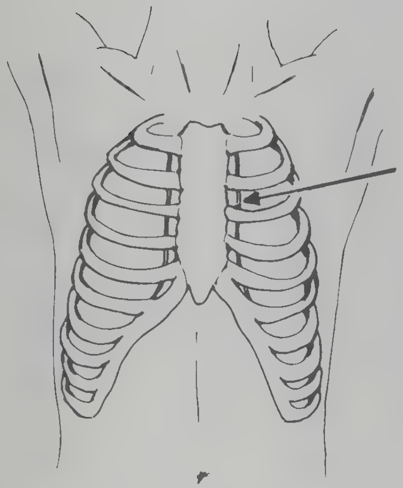
Surgical anatomy

1



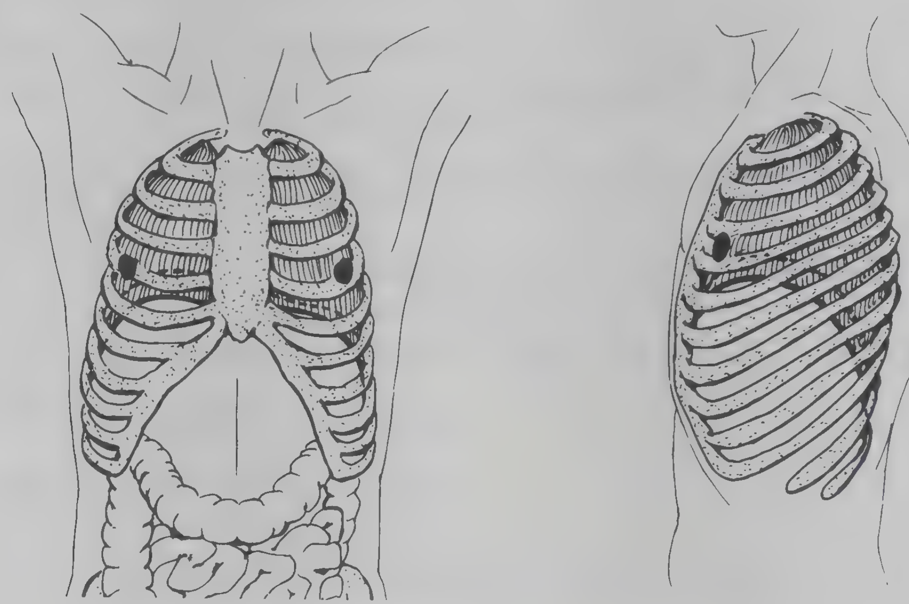
1 The chest wall is made up of the thoracic part of the spine, the sternum, the ribs, the intercostal muscles, and the external muscles of the chest and th back. Below each costa pass the intercostal vein, artery and nerve. The inter-costal vessels are one main source of hemothorax. Each lung is lined by a thin sheath – the pleura. The pleura consists of a visceral part fixed to the lungs, and a parietal part fixed to the chest wall. Between the two layers, a small amount of fluid is continuously excreted and absorbed, creating a slight vacuum between the two pleural layers. This vacuum attaches the lungs to th chest wall and keeps them expanded. If air (pneumothorax) or fluid (hemo-thorax) enters the pleural space, the lung will collapse.

2



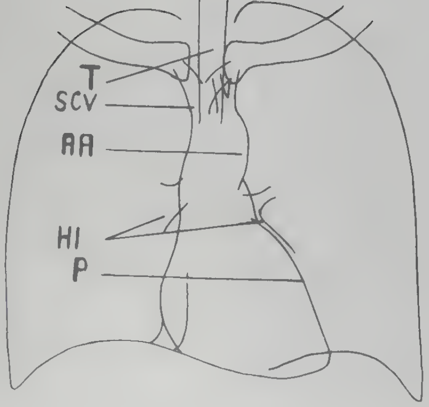
2 The internal mammary arteries run along the edges of the sternum. They are another common source of bleeding inside the thoracic cavity. Ligat them carefully in thoracotomy incisions close to the sternum.

3

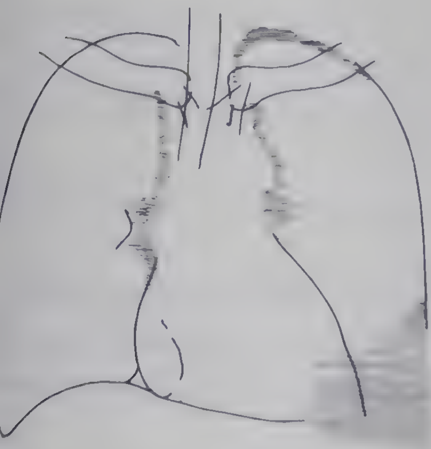


3 Note the extent of the abdominal cavity: One out of four wartime chest cases also has abdominal injury. The floor of the chest cavity is made up of diaphragm. During expiration the diaphragm reaches as high as the nip-ples (black points in the illustration). The abdominal injury is easy to miss as tears of diaphragm and hematomas on the posterior abdominal wall are often silent with few clinical signs the first hours after injury.

4



4 X-ray features – the mediastinum and the heart: The esophagus, trache (T), the arch of aorta (AA) and the decending aorta, the superior (SCV) and inferior caval veins are all located between the two lungs – in the mediastinum of the chest. The main X-ray indicator of hematoma formation in mediastinum is a wide mediastinum. Also look for blurring of the aortic arch, of the decend-ing aorta, of the hilum of the lung (HI), deviation of trachea (or a gastric tube) to the uninjured side, and hematoma at the top of the lung. The illustration als indicates hemothorax and/or contusion of the left lung. The heart is wrapped inside a fibrous tissue sheath – the pericardial sac. The pericardium has no elasticity: Even small amounts of fluid inside the pericardial sac will

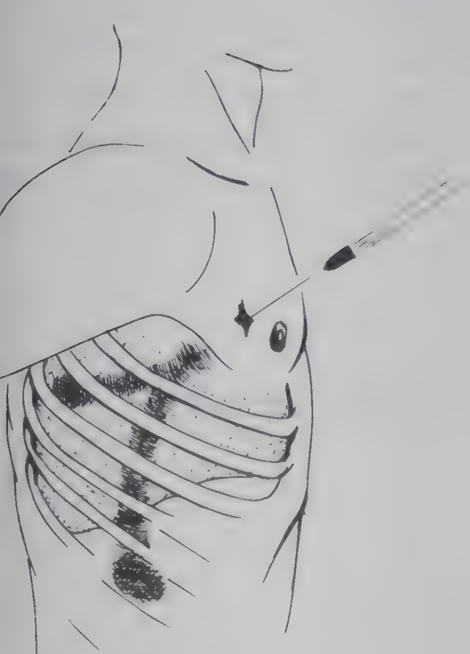


compress the caval veins inside the sac and the atrium of the heart, and cause cardiac tamponade. A wide contour of the pericardial sac (P) indicates pericardial hematoma. **Note:** Chest X-ray in bed: Mediastinum is wider and diaphragm at higher level compared to the upright position.

Types of wartime chest injury

Penetrating missile chest injury

- **Vascular injury:** The early mortality due to heavy bleeding is high. But still as many as one out of five cases with tears of the aorta may survive for hours after the injury. Urgent thoracotomy is indicated (ill 7 and 15).
- **Cardiac tamponade:** Bleeding from the heart or pericardial vessels into the pericardial sac will compress the heart – cardiac tamponade. Normally the clinical signs develop soon after injury: increasing pulse rate; increasing central venous pressure with visible congestion of the veins around the throat; and falling blood pressure. The mortality is high (ventricular fibrillation) unless the hematoma is evacuated: emergency subxiphoid incision (p. 347). **Notice** that the bleeding from a tear in the ventricular walls may be moderate with no early signs of cardiac tamponade: Monitor central chest injuries continuously for 24 hours after the injury.
- **Cardiac injury:** Patients with major injuries die before surgery can save them. Minor injuries, particularly of the ventricles, may survive for hours. For the experienced: Sternal split gives the best access to the heart. But tears in both ventricles may well be sutured through a standard left thoracotomy (ill 6 and 10).
- **Lung injury:** Due to the elasticity and excellent blood supply of the lung tissue, the early mortality is low. Out of ten cases, nine will manage with chest tube drainage as the only intervention, one must be explored (primary thoracotomy). With few exceptions, debridement of the lung wound track is unnecessary. The main concern is to avoid secondary complications by active respiratory exercises (p. 630).
- **Persisting hemothorax:** Early chest tube insertion and effective tube suction from the first minute are necessary to stop bleeding and air leak from the lung into the pleural space. When the lung is expanded towards the chest wall most bleeding and air leak stop spontaneously. The hemothorax persisting for one week will clot and produce pleural effusion: Then chest tube management is in vain, and decortication indicated. Also a persisting hemo/pneumothorax increases the risk of pneumonia, respiratory failure (ARDS) and secondary organ failure.



5 Thoraco-abdominal injury

It is common in high-energy missile injuries. Particularly missiles hitting the bones of the chest wall may fragment and change direction. Also fragments of the ribs and sternum may be accelerated through the diaphragm. The primary management is abdominal exploration and repair through a midline laparotomy

– and chest tube management. Primary thoracotomy is only done on strict indications (p. 345). The abdominal structures at risk are
- The spleen: Suspect splenic tear in circulatory shock cases and left-sided inj ry. Do urgent laparotomy (p. 411).
- The stomach and esophagus: Gastric tube is diagnostic. The management: p 399.
- The liver and posterior abdominal wall: Retroperitoneal hematomas and minor liver tears may have few clinical signs. Consider peritoneal lavage (p. 109). High-velocity hits on the right side in circulatory shock: Suspect majo tear of the liver – urgent laparotomy (p. 393).
- Diaphragm: The injury may be silent unless bowel sounds are heard inside t chest. Disturbed contour of the diaphragm or the lower part of the lung ma be the only sign shown on X-ray films. Abdominal exploration is mandatory the tear of diaphragm is normally sutured from the abdominal side (ill 13).

Blunt chest injury

This type of injury is common in city warfare (entrapment in buildings), mine casualties, other heavy blast wave injured, and after vehicle accidents. The ear clinical signs may be few even after high-energy traumas – the internal injury often missed initially. Continuous and close monitoring for 24 hours is necessary.

- **Lung contusion:** Chest pain, poor oxygenation (cyanosis) and ineffective respiration indicate major lung contusion. Based on clinical signs without X ray available it is difficult to distinguish lung contusion from hemothorax: Insert chest tube – also lung contusions may cause hemothorax. The mortal ty and risk of serious secondary complications are high (pneumonia, ARDS, secondary organ failure). The management: analgesia; oxygen; intensive ant biotic prophylaxis; Solumedrol 30 mg/kg, three injections the first 24 hour The mortality of severe lung contusion is high (pneumonia and ARDS).

Blast wave lung injury: p. 82.

- **Heart contusion:** The clinical signs are heart arrhythmia and pulmonary congestion after central blunt traumas. The management is conservative: bed-rest, digitalization and diuretics. If you suspect cardiac tamponade: subxiphoid incision (p. 347).
- **Hemothorax and/or pneumothorax** may also accompany a blunt chest injury. **Notice** that the early clinical signs may be few as the bleeding or air leak often is moderate.
- **Vascular injury:** Blunt traumas may cause ruptures of the aorta (tears of th descending aorta are most common) and the heart. Both the right and left ventricles are reached through a left standard thoracotomy incision (p. 346).

Preparations for surgery. Anesthesia

You manage most chest injuries with
- A general surgical set
- Chest tubes (8-11 mm)
- Suction unit.

French – mm conversion table: p. 143.

For thoracotomy we recommend
- Self-retaining rib retractors (Finochietto)
- Electro-cautery unit both for the incision and for bleeding control
- Sutures (2-0 Ti-cron, silk and Dexon) on long curved needles for lung tissue excision and bleeding control. Dexon no 2 to close the lateral thoracotomy. (Steel sutures for closure of the sternal split.)

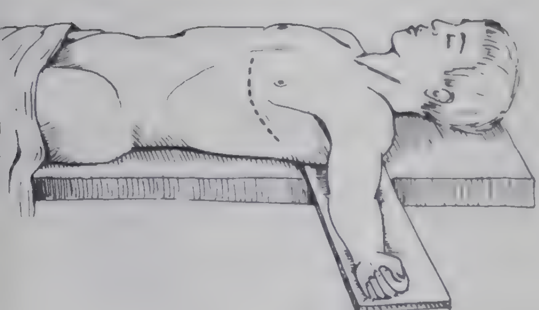
Preparations for surgery

hest tube insertion: p. 142.

- **Assess the basic life support:** Chest tube with suction and intrapleural chest tube analgesia are BLS procedures. They should start at the site of injury and continue until surgery. If not already established, BLS is done immediately on admission: Clotted chest tube or small caliber tube – insert one more tube. Heavy bleeding on the chest tube – insert one more tube. In patients without chest tube – intermittent i.v. morphine is the analgesia of choice. Fear always accompanies a painful chest injury: Do not use tranquilizers – their cumulative effect may cause respiratory depression. Effective analgesia is the best tranquilizer.
- **The blood loss:** Register the exact volumes of blood per hour by the chest tube. Indications for thoracotomy: See below.
- **Major unstable injury:** Do awake endotracheal intubation and start SIB-assisted ventilation if the respiration is poor. Consider immediate emergency thoracotomy.

hest tube bleeding – consider auto-
ansfusion: p. 270.

6 Standard thoracotomy, see p. 345: Lateral incision with the injured side up, side or half-side position supported with pillows. The arm is fixed on a pillow to give access to the surgeon. If you suspect injury also to the opposite side, the thoracotomy should be done with the patient lying on his back; the thoracotomy may then be extended through the sternum into the opposite pleural cavity.



7 Emergency thoracotomy, see p. 348: Right anterior lateral incision above the 6th or 7th rib, put a few towels under the left side. A separate abdominal incision may be done without changing position.

Anesthesia

The best anesthesia is general anesthesia with controlled respiration by endotracheal tube or tracheostomy. Also ketamine anesthesia is safe provided one lung is without injury. Thoracotomy may also be done with local anesthesia:
- Premedication with morphine-atropine
- and pleural analgesia: Dilute 100 mg bupivacaine with saline to 40 ml, give the solution by the chest tube
- and intercostal nerve block: Bupivacaine 5 mg/ml with adrenaline on six levels (eg. from the 3rd to the 8th rib) – 3 ml on each level.
- In an adult you may supplement with 10-20 ml bupivacaine-adrenaline 2.5 mg/ml as infiltration anesthesia without exceeding the maximum doses.

Chest wall injury

Flail chest

See p. 105.

Three or more rib fractures with intermediary fragments will cause instability of the chest wall – flail chest: The fractured area will move with expiration and inspiration. The respiration becomes ineffective and painful. Bone fragments may damage the pleura and lung, associated hemothorax is common. The pain prevents effective respiration: Pneumonia develops in those parts of the lung not inflated during respiration.

The management

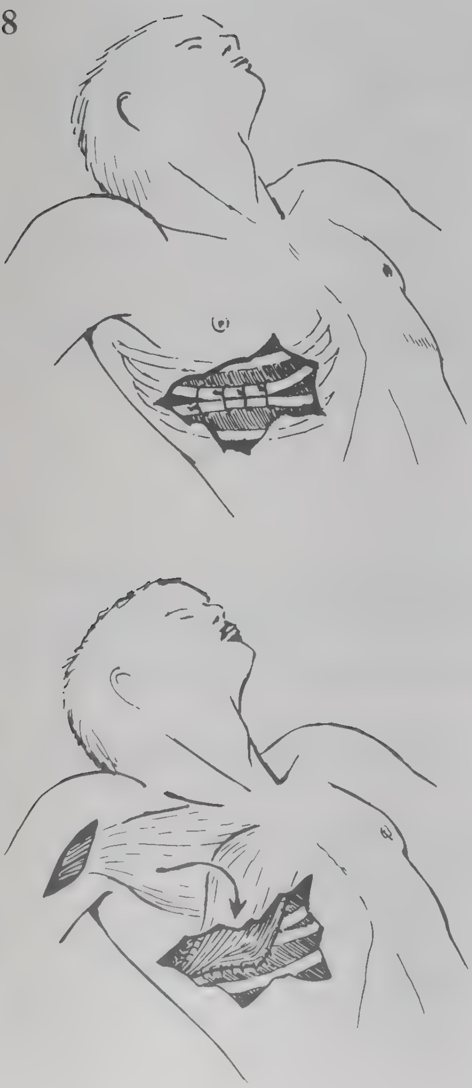
- Insert a chest tube if you suspect hemo/pneumothorax. Apply suction at intervals.
- Analgesia: Pleural bupivacaine analgesia by the chest tube, or intermittent i.v. morphine.
- Start active respiratory exercises (blow gloves) from the first day, continue for three weeks. Analgesia is essential.

Open injury

There is associated hemo/pneumothorax and lung injury. The rate of serious complications is high unless the chest wall is closed immediately.

- **Field management:** analgesia. Chest tube through the chest wall wound. Try to approximate the wound as best you can: deep sutures (2-0). Supplement with a sheet of plastic or rubber. Urgent definitive surgery.
- **Definitive surgery:** Extend the wound into a small thoracotomy. Inspect the lung. Debride the chest wall wound track exactly, and control bleeding. Insert double chest tubes (towards the top and base) through separate stab incisions, and close the chest wall.

8



8 **Closing major chest wall wounds:** Pull the ribs together (big towel clamps or stay sutures). Approximate thoroughly two ribs with interrupted sutures (Dexon no 2 or steel). Resection of parts of one intermediate rib may give better approximation of the wound edges.Then try to reconstruct the outer chest wall by separate sutures of each layer, leave the skin wound open. A minor air leak will probably stop within 48 hours due to increasing wound edema. In major air leak – you have to improvise: Mobilize a local rotation muscle flap (pectoral or latissimus) to cover the defect. Alternatively apply a thick split-skin graft or a fascia graft to seal the leaking area.

Injury in women

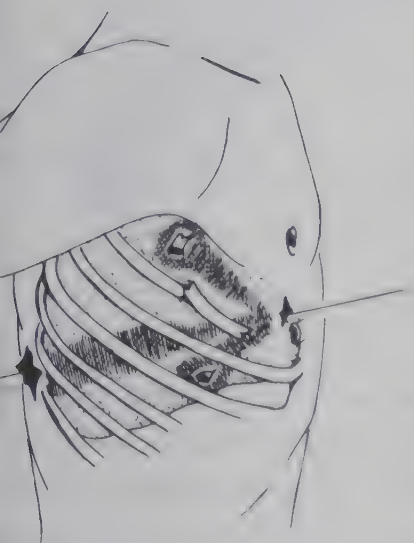
The breast consists of fatty tissue with rather poor blood supply. Debridement must be extensive. The wound is thoroughly drained and left open for delayed suture. Reconstructive surgery may be indicated.

Exploration of the chest – standard thoracotomy

Out of ten missile chest injuries reaching the clinic alive, one or two may need exploratory chest surgery.

Reasons for early thoracotomy

- Continued bleeding inside the chest despite effective chest tube management: 1500 ml or more on the first tube inserted. Or 500 ml/hour for three hours.

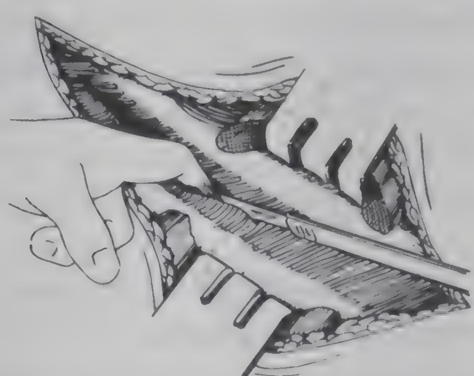


9 • Bone fragments and dirt buried inside the lung tissue: The risk of wound track infection, pneumonia and lung abscess formation is high unless the major fragments are removed.

- Open chest wall injury: The thoracotomy is done by the missile. Debride and extend the inlet wound, explore the lung and concentrate on chest wall closure.

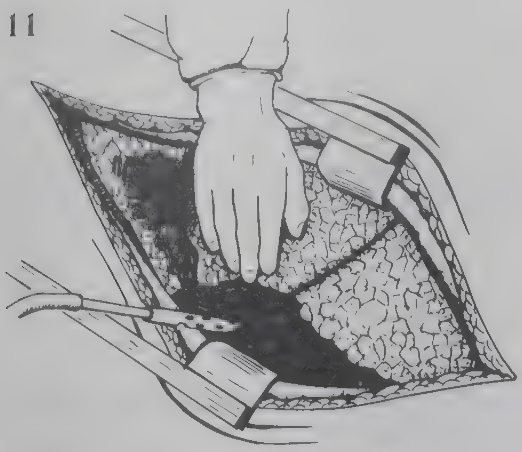
Reasons for secondary thoracotomy

- A clotted hemothorax: If not drained within one week the hematoma clots. Gradually it becomes organized, and some sort of a capsule will form around it. Even if you drain most of the blood and pleural effusion, the lung will not expand – the respiration and the chest wall movement become poor, the risk of respiratory failure is high. Thoracotomy with surgical excision of the capsule (decortication) should be done one week after the injury – before the hematoma is completely organized: Wash out the hematoma with warm saline, release the visceral pleura with careful blunt dissection. Late decortication of an organized hemothorax is technically difficult and carries high mortality.
- Lung abscess or fistula formation: If long-time tube drainage proves ineffective, thoracotomy must be done with decortication of the abscess capsule (p. 350). Also identify and manage the focus of infection (penetrating rib fragments, osteomyelitis).



10 Standard thoracotomy – the procedure: The level of incision depends upon the injury, commonly an incision below the 5th or 6th rib. The incision should be at least 20 cm long to give good access into the chest. It may extend from 2 or 3 cm lateral to the spine, pass two fingers below the scapula bone until the breast bone. Cut the muscles in the axillary fold with a knife or electrocautery knife. Incise the intercostal muscles mid-way between two ribs, or along the upper edge of the 6th or 7th rib to avoid bleeding from the intercostal vessel.

11

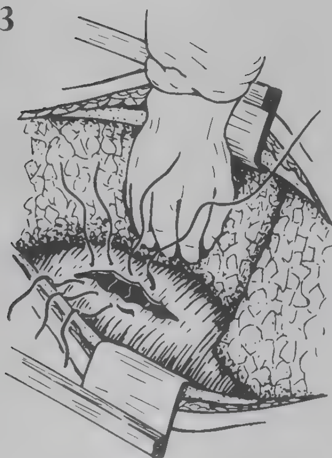


11 Control the bleeding: Puncture the pleura with a knife. You now enter the hematoma; the lung collapses and you may open the pleura wide. **Notice** Take care not to cut the internal mammary artery just lateral to the sternum. Evacuate the hematoma; consider autotransfusion if the bleeding is extensive Identify the bleeding source: Bleeding points in the chest wall are controlled ligature or electro-cautery. Minor bleeding points in the lung tissue are controlled by deep U-sutures.

12

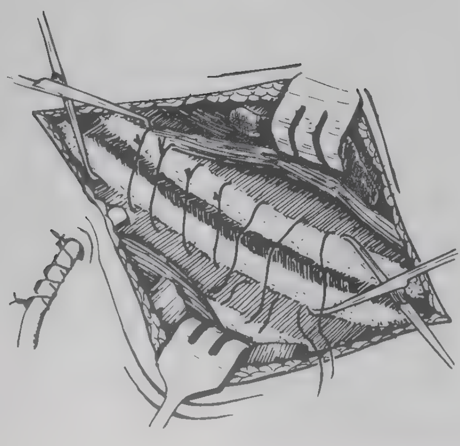
12 Lung resection may be done to control profuse bleeding from the lung. You may finger clamp the major vessels at the lung hilus to control bleeding, o compress the descending aorta (p. 348) until the bleeding is definitely controlled: Make a wedge-resection between long clamps, close the lung with deep Dexon 2-0 (or silk) interrupted or continuous interlocking sutures on a big curved needle. Lobectomy is seldom necessary. The lung tissue is not debride unless there is extensive destruction.

13



13 Tear of the diaphragm – approach through the chest: Retract the lower lobe of the lung upwards to identify the ligament towards diaphragm. Split the ligament with scissors and explore the diaphragm. If abdominal organ protrude through a diaphragmatic tear, replace the organs. Close the tear with interrupted sutures without debridement, insert chest tubes and close the thoracotomy. Immediately proceed with a midline laparotomy to explore the abdominal organs – do not carry out abdominal surgery through the thoracotomy. **Approach from the abdomen:** If you identify a diaphragmatic tear during a laparotomy, suture the tear from the abdominal side and insert chest tube. Thoracotomy is not indicated unless there is major bleeding from thoracic organs.

14



14 Closure of the thoracotomy: Before closure, apply two chest tubes, one towards the lung top, one towards the diaphragm. Pull the ribs together (large towel clamps) and close the chest wall tightly in one layer including pleura, intercostal muscles and ribs with strong interrupted sutures (Dexon no 2, silk no 1 or steel suture). For lateral incisions, the muscles of the axillary fold are closed in separate layers. Close the skin. Also close the missile wound track after debridement, but leave the skin wound open.

Post-operative care

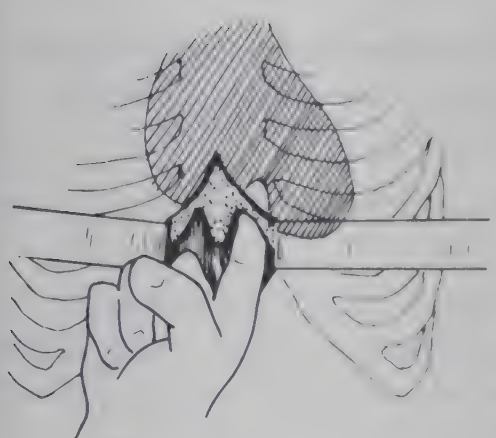
- Half-sitting position in the bed improves the ventilation of the lower parts of his lung.
- Effective analgesia is essential for effective respiration: Bupivacaine pleural analgesia by the chest tube and intermittent i.v. morphine.
- Repeated respiratory exercises to inflate the operated lung: Expiration against resistance by blowing surgeon's gloves.
- Intermittent suction on the chest tubes. Note the volumes drained to monitor total blood loss.
- Out of bed with support the first day after surgery, or at least bed-side sitting, with respiratory exercises.

Cardiac injury

Close monitoring

Suspect cardiac injury in midline injuries and all high-energy chest injuries. The clinical signs of heart contusion, penetrating injury and cardiac tamponade (p. 341) may develop gradually – monitor closely for 24 hours:

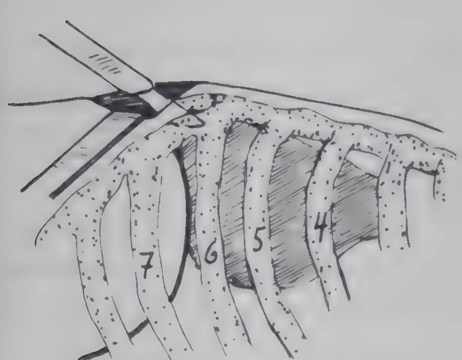
- The heart rate and arrhythmia
- The venous pressure, venous congestion
- The respiratory quality, lung congestion, cyanosis
- The blood pressure
- Repeated chest X-ray if available (p. 340)



Basic life support – manage cardiac tamponade

The clinical signs are increased pulse rate, increased central venous pressure with congestion (visible) in the superficial veins of the neck, and falling blood pressure. Evacuation of hematoma in the pericardial sac is an emergency procedure to be done there and then – in the field, during the evacuation or immediately at admission. You may try to aspirate the hematoma through a large-bore needle (subxiphoidal puncture). There are some problems with this method: It is difficult to decide whether aspirated blood is from the heart or from the pericardial sac. And the needle aspiration is dry if the hematoma has become organized.

15 Pericardial drainage by subxiphoid incision: The procedure is simple, safe and rapid. It is done under local or ketamine anesthesia. Make a short incision from the xiphoid process downwards; incise the superficial abdominal fascia exactly in the midline. Identify the pericardial sac by blunt finger dissection behind the costal arc close to the bone. Incise the pericardium with a knife. An organized hematoma is washed out with warm saline.



or the experienced surgeon: Sternum split gives the best access to the eart and mediastinum.

Definitive surgery

Both ventricles are reached through a left anterior thoracotomy (ill 6 and 10). Split the pericardium in front of the left phrenic nerve and expose the heart. Bleeding from minor tears is controlled by finger pressure until the sutures are tied.

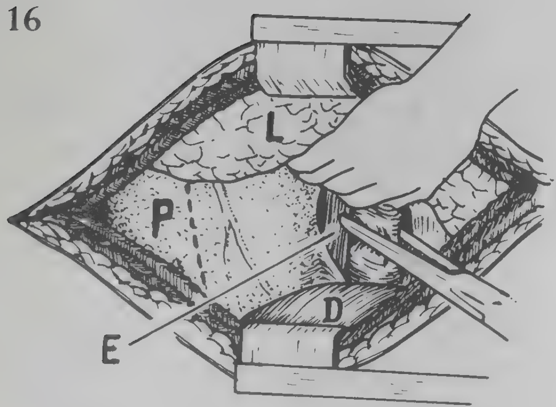
- Atrial and caval injuries: Apply exclusion clamp to control bleeding. Repair by continuous suture (4-0 Prolene or silk).
- Ventricular injuries: Repair by interrupted U-sutures (4-0 Prolene or silk). The heart muscle is easily torn, and direct suture may cut through the muscle. If so, cut two strips of pericardium and set the suture through the strips. **Notice:** Identify the coronary arteries; they are normally seen on the cardiac surface – do not close them with the sutures.

Emergency thoracotomy

Cases with major vascular injury that cannot be controlled by compression: Do not waste time on forward conservative field management. Do emergency thoracotomy with temporary clamping of the aorta – or the patient will die. Forward mobile clinics should be prepared to perform emergency thoracotomy. Done early, the procedure is life saving in one out of five missile injuries to the major vessels of the chest and abdomen.

Indications
- Abdominal injury in grave circulatory shock that does not respond to aggressive volume therapy: Clamping of the descending aorta is done before the abdomen is entered.
- Chest injury in grave circulatory shock that does not respond to aggressive volume therapy: Temporary clamping of major bleeding vessels.
- Penetrating cardiac injury: Definitive surgery.

16



16 **Emergency thoracotomy – the procedure:** Insert gastric tube for easier identification of the esophagus during surgery. If possible, work with two surgical teams in abdominal cases. The thoracotomy is done with the patient lying on his back, the left side slightly elevated (p. 343). Make a left anterior thoracotomy incision from 2 cm lateral to the sternum as far dorsal as possible in the 5th or 6th intercostal space. Apply a Finochietto retractor. Retract the left lung (L) upwards, identify the ligament between the lung and diaphragm (D) – and split it with scissors. You then have access to the pericardium and the aorta. Esophagus (E) is situated in front to the right of aorta: Identify it so as not to damage the phrenic nerve attached to the pericardium or esophagus. The aorta is covered by the parietal pleura – incise it just in front of the vessel. **Control abdominal bleeding:** Apply a clamp to the thoracic aorta as close to the diaphragm as possible, then explore the abdomen through a separate midline incision. If aorta clamping is needed for more than 30 minutes, open it at intervals to prevent ischemic damage to the spinal cord and abdominal organs. **Manual compression of the aorta:** The inexperienced may go directly for the descending thoracic aorta without mobilizing the lung. Compress the aorta against the spine with one hand. Compression is tiring and is difficult to maintain for a long time without

clamping. **Internal cardiac massage:** The anterior left thoracotomy gives good access to the pericardial sac (P). If the patient needs external heart massage, incise the pericardial sac (dotted line) and perform massage by compressing the heart against the sternum. **Removing the clamp:** Before you remove the aortic clamp, start flushing blood and fluid through all i.v. lines. The clamp has to be removed gradually, releasing the compression stepwise during 5-10 minutes. Manual compression is a good way to gradually decrease the clamping. If you release the clamping rapidly, the blood pressure will fall due to the dilated vessels below the diaphragm, and the patient collapses in hypovolemic shock. Monitor the blood pressure closely during clamp release. **Complications of aortic cross-clamping:** There is always risk of hypoxic spinal cord injury after cross-clamping. This risk is reduced by applying the clamp as distally as possible on the thoracic aorta. Clamping for more than 30 minutes risks ischemic injury to abdominal organs; failure of kidneys, liver and pancreas may occur. Intestinal ischemia may cause septicemia, give broad-spectrum antibiotics for 24-48 hours after the clamping.

Complications of injury and surgery

Monitoring after surgery: Most complications develop during the second week after the injury.

Pneumonia

It increases the risk of secondary organ failure. Pneumonia is the most common complication of chest injury and lack of post-operative care. With poor respiration, mucus and debris will block the lower segments of the lung making them a focus for infection. Lung segments not inflated also collect mucus. The preventive measures are

- Effective analgesia
- Tracheal suction in weak patients
- Early mobilization
- Continuous respiratory exercises

Without these preventive measures antibiotics have no effect.

Lung failure (ARDS)

Secondary organ failure after surgery: p. 588.

Patients with major chest injury, in particular a major lung contusion, carry high risk of secondary organ failure. The mortality in ARDS is high; concentrate on preventing post-operative pneumonia. High-energy nutrition is essential.

Clotted hemothorax

Hemothorax not evacuated within one week clots and becomes organized: Respiration is impaired, increasing the risk of pneumonia and lung failure. The management is early decortication through a small thoracotomy.

Lung abscess

A poorly drained hemothorax may become infected and form empyema. Bone fragments and dirt left inside the lung tissue after a high-energy missile injury may also cause abscess formation. The abscess signs are:

- Abscess temperature: The fever usually rises to peaks and falls to normal or below normal temperature at irregular intervals.
- Decrease in general condition: The patient becomes weaker, loses appetite and weight.
- There is dull drum sound and poor respiratory sounds over the abscess area. On suspicion of abscess formation: Do diagnostic puncture with a large-bore needle. Dry taps do not exclude the presence of an abscess – the abscess fluid may be thick and organized.

When the diagnosis is confirmed, the abscess must be evacuated. **Step one:** Support the patient with potent antibiotics and insert a large-bore chest tube through a stab incision. The discharge through the tube will diminish after some days: Forward or withdraw the tube a little for better drainage. Do not remove the tube until it stops draining completely. In young patients the tube evacuation is usually successful and the lung will expand well. **Step two:** If the tube does not drain, or if the lung does not expand within one month, make a small thoracotomy. Then wash out the abscess. If there is an organized abscess capsule, excise it. Insert drains and leave them until they are non-productive (it may be months). **Consider: What is the focus of the infection?** Major fragments (2 cm) of bone, dirt or metal buried inside the lung tissue should be removed by thoracotomy. A focus of osteomyelitis in the chest wall should be excised.

Lung fistula

An abscess may rupture spontaneously through the chest wall and form a fistula. In some cases the fistula will dry and close after potent long-time antibiotic treatment. In most cases a small thoracotomy and decortication must be done.

Osteomyelitis

This may develop in the chest wall bones. The management is surgical excision of necrotic bone, drainage and long-time antibiotic therapy.

Points to note – Chapter 26

Find out if the injury is penetrating or not
- learn the clinical examination: p. 110
- train to do diagnostic peritoneal lavage: p. 109
- do not miss associated chest injuries: p. 112 and 340

How to select the patients who need urgent laparotomy
- know the priorities for laparotomy: p. 353 and 356
- note the reasons for emergency laparotomy: p. 156

Train in emergency laparotomy guided by expert staff
- note the importance of early control of abdominal bleeding: p. 131.
- learn the surgical technique of midline incisions: p. 360
- learn the routine for abdominal exploration: p. 361-365
- study carefully the surgical anatomy of each abdominal organ: Chapter 27-Chapter 33. Learn to identify the abdominal aorta and main abdominal arteries, and how to control them by manual compression or finger clamping: p. 365-366
- know how to control bleeding by temporary gauze packing: p.365-366
- the emergency laparotomy should not last more than one hour. Note the importance of central warming of cold patients: p. 153

Train in emergency management of intestinal injuries
- note the clinical signs of intestinal injury: p. 110
- note how important it is to prevent peritonitis: p. 98
- train to do diversion enterostomies guided by experienced staff: p. 378
- damaged sections of the intestine may also be tied in emergencies: p. 371

Learn how to close the abdominal wall
- insert more than one drain before closure: p. 368
- note the importance of naso-gastric tube decompression: p. 368
- learn the surgical technique of abdominal wall closure. Note the relief sutures: p. 370
- know how to improvise if the abdominal wall is damaged, or the abdomen distended: p. 359

Anticipate the main complications after abdominal surgery, know when to reoperate: p. 459

26 Abdominal injuries in general

Priorities for surgery

Unstable, bleeding abdominal injuries – one-hour limit on surgery

Abdominal high-energy injuries (both penetrating and blunt) are often extensive. To control all bleeding points and repair all organs injured is time consuming. Prolonged surgery causes hypothermia. There is no benefit in laparotomies lasting more than one hour on unstable cases.

Two-step surgery in unstable injuries:
- The day of injury: Control bleeding with gauze packing. Close or tie wounds of the intestine. Close the laparotomy without drainage. Concentrate on intensive basic life support.
- Within 48-72 hours: Remove the gauze packs – most bleedings would have stopped; the patient is in a stable circulatory state. Do the definitive surgery with organ repair.

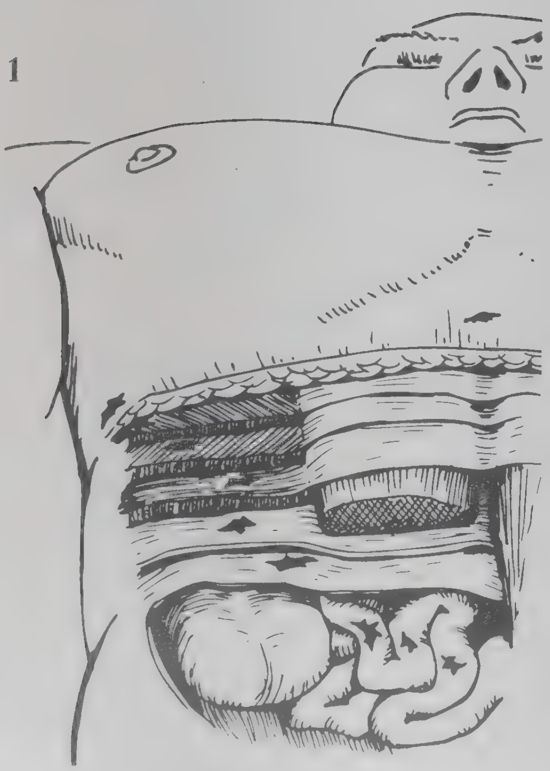
For details: Emergency laparotomy – p. 370.

Penetrating abdominal injury

All missile abdominal injuries are managed by laparotomy and exploration of the abdomen. There are no exceptions to this rule. There should be no delay due to extensive diagnostic procedures. The routine examinations before surgery are simple and rapid:
- Careful clinical examination of the chest, abdomen and pelvis, including manual rectal exploration
- Gastric aspiration and decompression by naso-gastric tube
- Bladder catheter
- Femoral pulse beat examination
- Rough neurological examination of the lower limbs
- Chest X-ray
- Hematuria: High-dose i.v. contrast urography to exclude damage to both kidneys

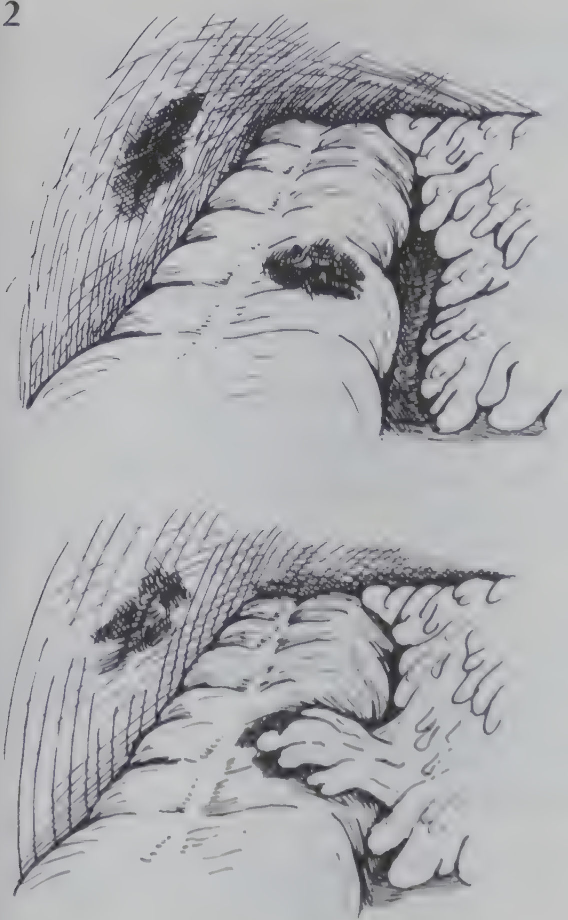
The main diagnostic problem
It is difficult to diagnose which injury is really penetrating. Small high-velocity shrapnel may leave only a tiny inlet wound in the abdominal wall: Undress the patient completely and wash him well so as not to miss the inlet. **Note:** The missile may fragment and change direction inside the body. Also examine the buttocks, perineum (mine injuries), the back and the chest for possible inlet wounds.

1



1 **No use to probe the wound track:** Several layers of abdominal muscles and their fascia constitute the abdominal wall. The missile track through the abdominal wall is not straight, and the separate tissue layers will move in relation to each other: You cannot tell by using a simple probe into the wound whether the missile has entered the abdominal cavity or not.

2



Wounds of the diaphragm are sutured from the abdominal side.

2 **The penetrating injury may be "silent":** The abdominal cavity is lined with a mucosal sheet, the peritoneum. The intestines are covered with a fat tissue apron, the omentum. The peritoneum and omentum are the "abdominal surgeons": They try to cover and close any wound inside the abdomen – the penetrating injury may be silent and rather painless at the time of examination. In particular tiny perforations of the small intestine are often missed at the time of injury. But within 4-5 days the seal is broken, peritonitis develops, and makes you recognize the full extent of the injury. A missed intestinal injury carries a high risk of complications and death.

Possibly penetrating injury
- Consider peritoneal lavage if the injury is low energy.
- In high-energy injuries: Manage the case as if the injury is penetrating do laparotomy without further examinations.
- The incidence of negative laparotomies (where no injury is found) should be about 20%.

Combined penetrating injuries

One out of four abdominal injuries also has injuries outside the abdominal cavity:
- **Associated chest injury** is most common. The chest injury has priority and should be managed before the laparotomy is done. In most cases chest tube insertion is the only management necessary.
- **Associated pelvic injury:** Unless major pelvic vessels are injured and the patient is unstable, the abdominal injury has priority. Close or resect intestinal wounds before the pelvic injury is explored. Most pelvic injuries are managed by gauze packing (bleeding) or drainage (tears of the rectum, bladder and female organs).
- **Associated spinal injury:** The abdominal injury has priority. Intestinal injuries must be repaired before the spinal injury is explored. You may delay spinal surgery for 48 hours (unless there are increasing neurological signs) if that is necessary to repair the abdominal injury.

Blunt abdominal injury

This type of injury is common in city warfare (entrapment cases), after blast and mine injury and vehicle accidents.

Diagnostic problems

Major and bleeding blunt abdominal injuries are managed by emergency laparotomy without further delay. But most blunt abdominal injuries are circulatory stable at the time of primary surgery: Bleeding from tears of the liver and kidney would have normally stopped spontaneously. The clinical signs of internal organ injury may be few. These cases represent a diagnostic problem: Intestinal tears and retroperitoneal injury (colon, duodenum, pancreas) are often missed.
- Perform diagnostic peritoneal lavage.
- If intestinal injury cannot be excluded, do laparotomy – even if the patient is circulatory stable.

Conservative management of blunt injuries?

Blunt injuries to the liver, kidney, pancreas and spleen may heal spontaneously and go without surgery. But there are definitive conditions for non-surgical management:

- Advanced X-ray monitoring.
- Close laboratory monitoring (the coagulation system).
- An experienced surgeon should continuously monitor the patient and the X-ray films for 48 hours after the injury.

As these conditions are seldom at hand in forward wartime surgery, we advice that the main management strategy for blunt abdominal injuries – even in stable cases – is exploratory laparotomy. The specific organ injuries are managed as in penetrating injuries (Chapters 31-40).

Do not miss associated blunt injuries

Multiple blunt injuries are common – three out of four abdominal cases also have injury outside the abdomen. Most common are:

Blunt chest injury: p. 342.
Pelvic fractures: p. 477.

- Chest injury, in particular, lung contusion and rib fractures
- Pelvic injury, in particular, pelvic fracture bleeding

Priorities for surgery

Assess the risk of complications

- Penetrating abdominal injuries operated within three hours after the injury: The death rate is one out of ten injured.
- Penetrating abdominal injuries operated more than ten hours after the time of injury: The death rate is five out of ten injured.

Guidelines for clinic triage of abdominal cases

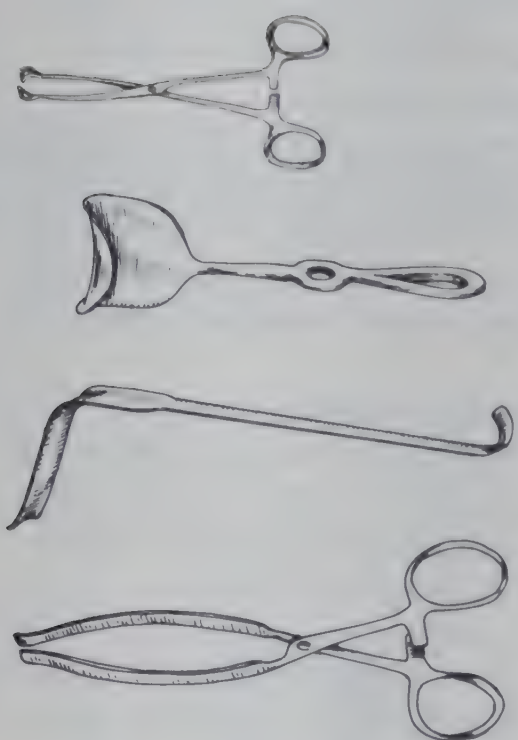
Emergency laparotomy: p. 370.

- **Emergency laparotomy:** Patients in grave circulatory shock. The laparotomy is the only effective basic life support. Note the one-hour limit. Consider emergency thoracotomy with aortic clamping before you enter the abdomen.
- **Urgent:** Unstable cases with ongoing abdominal bleeding. The management: (1) Control external bleeding. (2) Transfusion (O blood) and volume therapy through double large-caliber i.v. lines. (3) Laparotomy without further examination – note the one-hour limit.
- **Can wait:** You may delay surgery in cases that are circulatory stable – if the injury is less than four hours old. The management: (1) Fulfill the basic life support procedures – the objective is hemoglobin level of 9 g/100 ml and hematocrit at 20. (2) Fulfill the diagnostic procedures (chest X-ray and urography) and the routine preparations for laparotomy. (3) Exploratory laparotomy – you may exceed the one-hour limit.
- **Must wait:** Cases late for surgery – the risk of complications is high and does not increase much with delayed surgery. The management: (1) Basic life support. (2) I.v. broad-spectrum antibiotics in high doses. (3) Laparotomy: Concentrate on establishing a diversion stoma and effective drainage. Note the one-hour limit.

Preparations for surgery. Anesthesia

Supplement to the general surgical set:
- Long surgical scissors (20 cm)
- Long forceps (20 cm)
- Five long artery forceps (20 cm)
- Long needle holder (20 cm)
- Gauze packs (30x30 cm) and ribbon gauze
- Small metal cup (to remove blood)
- Suction (hand or pedal pump)
- Saline solution for intraperitoneal washing
- Suture materials: absorbable suture (1 and 3-0). Absorbable suture (2-0) on large curved needle for liver suture. Without absorbable suture, silk suture will do.
- Electro-cautery is not necessary, but time saving.
- Vascular instruments and suture materials should be at hand.

3



3 Particular instruments for abdominal surgery
- Two soft intestinal occlusion forceps
- Two intestinal grasping forceps (Babcock)
- Abdominal wall retractors
- S-shaped intestinal retractor

Preparations for surgery

Check list:
- The perineum, buttocks, back and chest examined for missile inlet wounds.
- Naso-gastric tube inserted.
- Bladder catheter inserted.
- Two large-caliber i.v. lines running.
- Expect a blood loss of 500-1000 ml during surgery on stable cases: blood-type. Consider autotransfusion.

Antibiotics before surgery – a one-time dose:
- Alternative 1: I.v. ampicillin 2-4 g
- Alternative 2: I.v. penicillin 10 mega IU and doxycycline 400 mg
- Alternative 3: I.v. chloramphenicol 1g
- For all cases: Infusion metronidazole 1.5 g

Factors interfering with abdominal surgery
- "Have you been operated on before?" After abdominal surgery, adhesions develop inside the abdominal cavity, especially so after surgery in infected cases. In that case you may find a pack of intestines fixed to the peritoneum on the abdominal wall: Be careful with the abdominal wall incision. Prepare for difficult dissection and prolonged surgery.
- "Did you have any abdominal illness? Chronic dysentery (amebiasis)? Schistosomiasis? Typhoid fever? Ascariasis?" These diseases may all cause serious complications during and after abdominal surgery.

Diseases interfering with surgery: p. 281.

For the operating theater nurse

- Make a list of all surgical instruments and the exact number of gauze packs before surgery starts.
- Check the list before closure of the abdomen: Make sure that no items are left inside.
- Wash a field from the nipples to the mid-thigh.
- Make tilting of the operating table possible: Surgeon's access to the upper abdomen is better with the patient tilted with head up, feet slightly down. Tilt the table the other way for access to the lower abdomen.

Anesthesia

Relaxation of the abdominal wall muscles is essential for exact exploration of the abdomen, and for repair of major abdominal wall injuries:

- **General anesthesia with controlled ventilation** is the best method: Muscle relaxation makes the surgery easier, and the tracheal tube prevents aspiration of gastric contents to the lungs.
- **Bupivacaine spinal anesthesia** is a safe method. The anesthetic level should at minimum reach Th6, at best Th4 (the nipples). You may supplement a low spinal anesthesia (below Th6) with intercostal nerve block (observe the maximum doses) or i.v. ketamine anesthesia.
- **Ketamine anesthesia** does not provide muscle relaxation. But intermittent i.v. ketamine is simple and rapid – it may be the method of choice in some emergency cases: Emergency thoracotomy with clamping of the aorta may be done, also temporary gauze packing of abdominal bleeding through a wide midline incision. For further surgical repair, muscle relaxation is necessary.

The intestines themselves are insensitive. The main source of pain is traction and manipulation of peritoneum and the mesentery.

Particular problems with anesthesia during abdominal surgery

- The surgeon should be there: Stable but hypovolemic patients may develop circulatory shock immediately when the anesthesia is given. Flush the infusions and start surgery without delay: When surgery starts and there is some manipulation with peritoneum, the blood pressure will rise.
- Distended abdomen – beware when the abdomen is entered: Major bleeding inside abdomen may stop spontaneously due to increasing pressure inside the abdominal cavity – tamponade effect. When the surgeon enters the abdomen, the bleeding may start and the circulation may collapse.
- Monitor the heart: Much manipulation with the intestines affects the heart. Beware when the small intestine is delivered out of the abdomen during the exploration.

Abdominal wall injury

Missile wounds

The energy wave from the penetrating missile may separate the layers of the abdominal wall: Hematomas may collect between the muscles. Explore the wound track well to the sides. Drain hematomas through separate skin stab incisions. Close the wound with a few interrupted deep muscle sutures. Do not debride or suture peritoneum. Leave the superficial parts of the wound open for delayed suture.

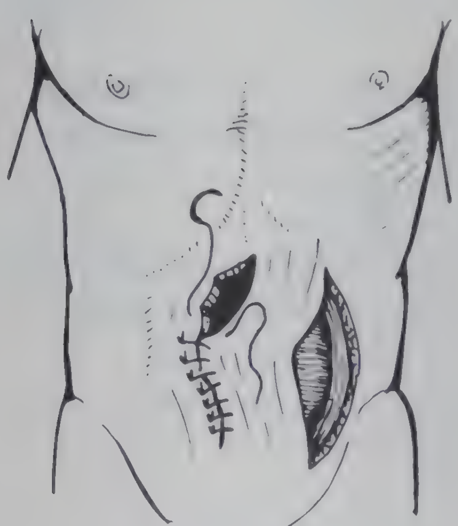
4

Split infusion bags may be used to close defects of the abdominal wall.

4 Major abdominal wall injury – temporary closure: As an emergency procedure before evacuation, any clean nylon, rubber or canvas sheet may be used as a "temporary prosthesis". Cut the sheet to fit the abdominal wall defect and fix it with some sutures. Synthetic materials (silicone, Silastic) cause infection, and should not be used for permanent closure of large defects in wartime injuries.

Evisceration – intestines delivered through the abdominal wall:
No intestinal perforation – wash and deliver the intestines into the abdominal cavity and close the wall defect. With intestinal perforation: Close or resect the intestinal tear, then deliver the intestines inside. Or leave the perforated loop outside the abdominal wall over a rubber tube/plastic rod, and close the abdominal wall defect temporarily. Laparotomy with definitive intestinal repair should be done within 6-8 hours after injury.

5



5 Major abdominal wall injury – definitive closure: The minimum objective of the primary surgery is to close the skin defect. Ventral hernias are managed later – see any textbook in abdominal surgery.

- Alternative 1 – skin flaps: Make two parallel longitudinal relief incisions, one on each side of the wound. Mobilize the skin bridges and suture them side-to-side to cover the defect. The skin bridges should be at minimum 10 cm wide to maintain their blood supply. The relief incisions are closed by split-skin grafts.
- Alternative 2 – skin-muscle flap (illustrated): Make a longitudinal incision through the skin and muscle but not through the peritoneum. The skin-muscle bridge between the wound and the incision is carefully mobilized from the peritoneum. The defect is closed by direct suture. The relief incision is left open for skin grafting or spontaneous granulation. Apply some broad bands of adhesive plaster to relieve wound tension.
- Alternative 3 – the rectus rotation flap: p. 201.

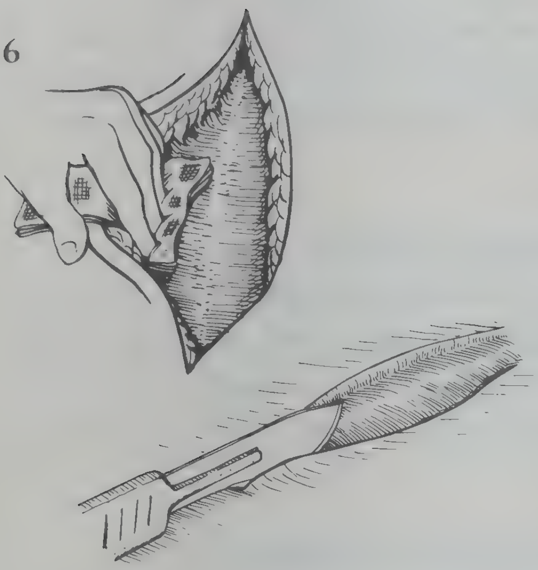
Extensive defects

They can only be partly closed by the above listed methods. To cover the remaining defect, mobilize the omentum, fix it to the wound edges as a "floor" in the abdominal wall wound. Apply large saline-wet gauze packs inside the wound. Keep the gauze constantly moist, change the packs every 4-6 hrs. After one week the defect is covered with granulations and may be closed with split-skin grafts.

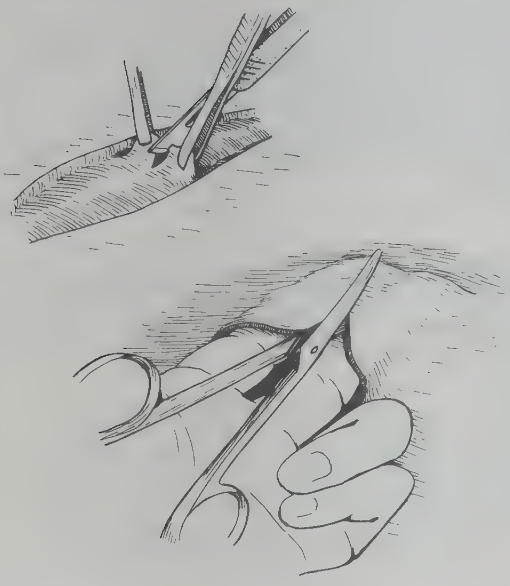
The midline incision. The exploration

The midline incision is the standard wartime incision for abdominal exploration and surgery:

- Wartime injuries are multi-organ injuries. By extending the midline incision from the sternum to the pelvic bone, you can explore and manage each abdominal and pelvic organ.
- The incision is rapid, simple and heals well.

6


6 The midline incision: Depending upon the injury you start with a proximal or distal incision. Extend it without hesitation beyond the umbilicus. Cut through the skin down to the fascia exactly in the midline. Control bleeding by application of retractors upon gauze, and clamping of some arteries. Sweep the fat aside with "gauze fingers", and identify the midline in the fascia. Incise the fascia by knife, and extend the incision by scissors. You can now see the peritoneum bulge through the incision.

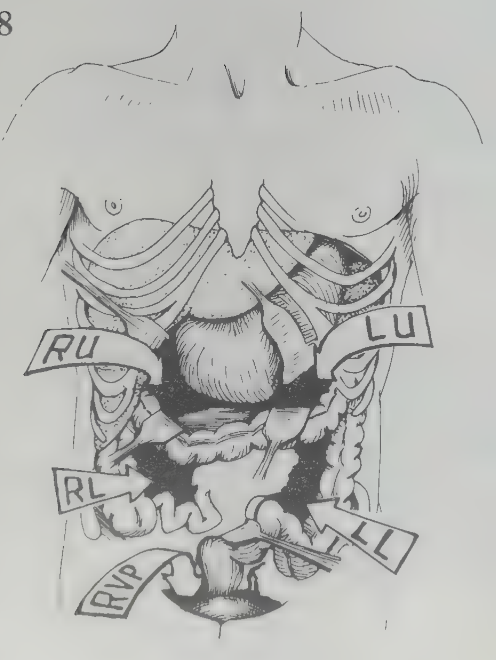
7


7 Open the peritoneum: Grasp the peritoneum and open it between two forceps. Be careful not to grasp the intestines. Extend the peritoneal incision with two fingers inside the abdomen to control the intestines. Distal midline incision: Do not cut the urine bladder when you approach the pelvic bone.

Systematic exploration!

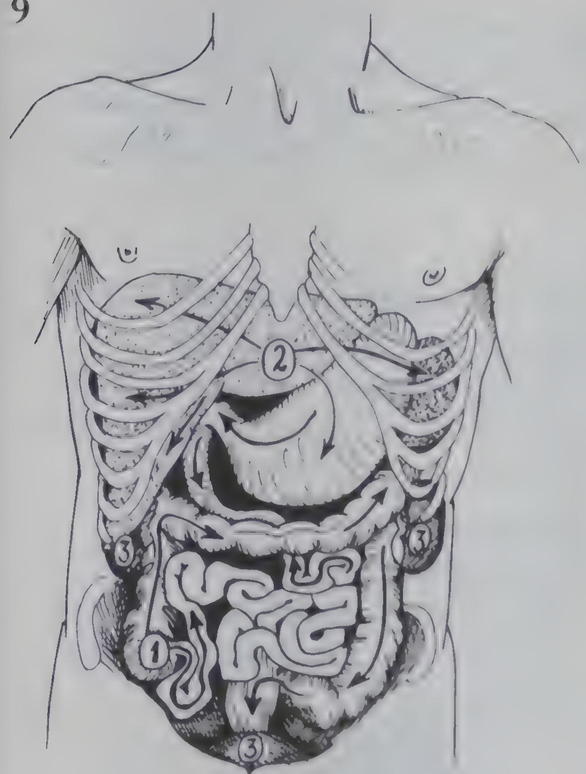
To reduce the operation time without missing injuries, the exploration should follow a stepwise routine. It does not matter that the routines differ between surgeons – the key is to work systematically. Do not leave your routine, do not leave any organ unexplored.

- **Step one:** Without exception – explore the four abdominal quadrants and the rectovesical pouch for bleeding (ill 8) and retroperitoneal hematomas. Control bleeding before you proceed to step two.
- **Step two:** Without exception – explore all organs inside the peritoneal cavity (ill 9). Clamp intestinal tears temporarily as you identify them.
- **Step three:** If indicated, explore the retroperitoneal organs (ill. 17- 20).

8


8 Where blood collects – the four abdominal quadrants: The right lower quadrant (RL) – retract the small intestines to the left with a large gauze pack, explore the space medial to the right colon. Left lower (LL): Retract the small intestines to the right, explore the space medial to the left colon. Right upper (RU): Retract the transverse colon downwards, the liver upwards, and explore the space under the right lobe of the liver lateral to the duodenum. Left upper (LU): Retract the stomach towards the midline, the transverse colon downwards, and explore the space under the spleen and the left lobe of the liver. The rectovesical pouch (RVP): Tilt the table head down, retract the small intestines upwards, explore the space around the rectum behind the bladder.

9



9 Step two – the routine abdominal exploration: (1) the intestines: Identify the right colon and explore the small intestines including the mesentery to its proximal part and back again. By this two-time examination you may avoid the most common mistake – that of missing a tiny perforation. Proceed along the right colon, the transverse colon, the left colon and sigmoid down to the rectum. If you suspect injury on the posterior wall of the colon, do not hesitate to mobilize the colon or the rectum for inspection (ill. 14).

(2) the upper abdomen: the liver, spleen, stomach and duodenum. **Note** the most common mistakes: Rough exploration may make a hematoma in the liver or spleen bleed. Tears of the posterior wall of the stomach are missed (mobilization – ill. 18). Retroperitoneal injuries of the duodenum are missed (mobilization – ill. 19).

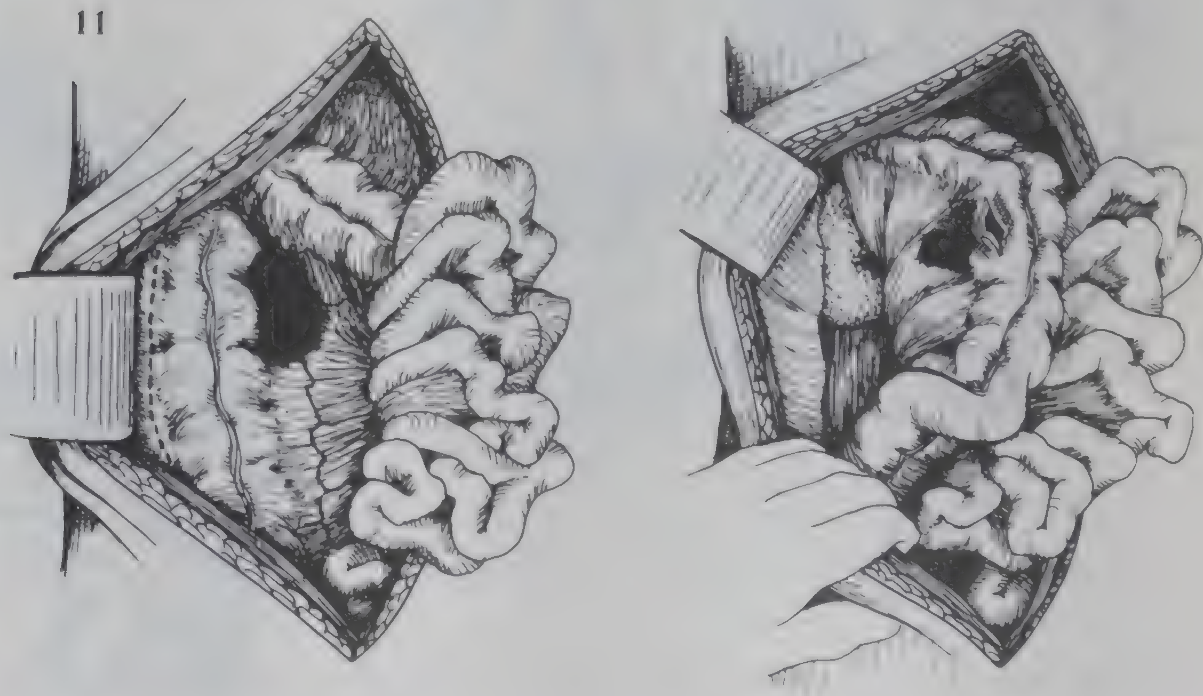
(3) the urogenital organs: both kidneys with ureters, the bladder and the female organs. **Note** the common mistakes: missing a tear of ureter or entering a retroperitoneal hematoma at the kidney without first gaining control of the renal vessels (ill. 20).

10

The exploration in detail

10 The small intestine: Examine every cm methodically – both sides of the intestine and the mesentery. Perforations are clamped when identified. Control bleeding mesenteric vessels with clamp and ligature – and observe the blood supply to the intestine: Cyanosis indicates resection and end-to-end anastomosis.

11

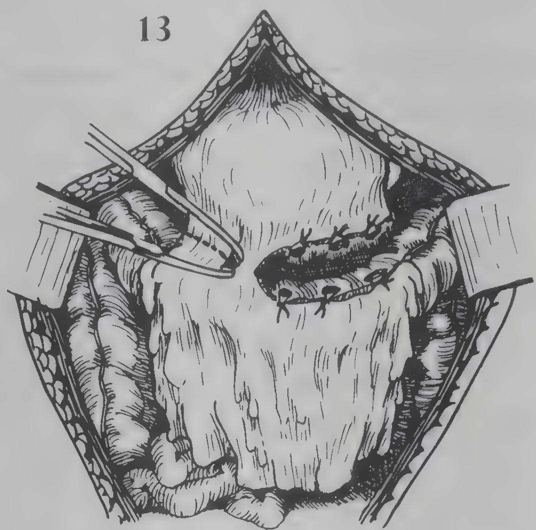


11 The right colon, the right kidney and ureter: Cover the small intestine with large saline gauze packs and retract them to the left. You may deliver the whole pack of small intestine outside the abdomen for better exposure. Retroperitoneal hematoma or local swelling close to the colon indicates a tear of the colon (or the right kidney) behind the peritoneum – mobilize the colon: Incise the peritoneum along the dotted line in the bloodless area just lateral to the colon. Mobilize the colon by blunt finger dissection, lift it towards the midline for inspection. This is also the best access to the right kidney.

12

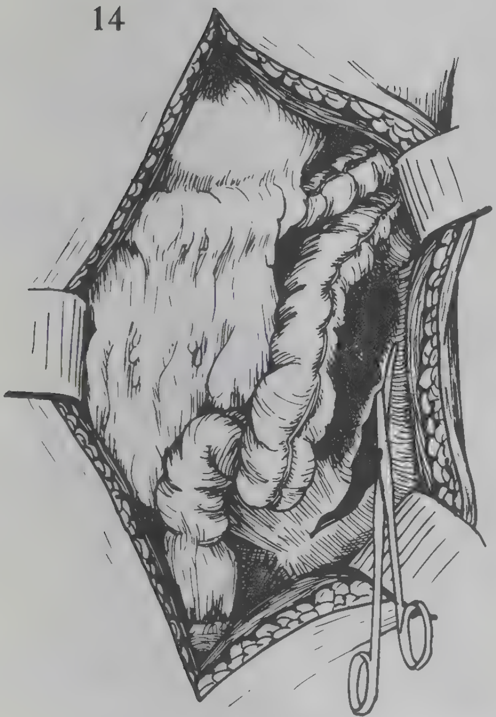
12 **The transverse colon** is inspected by retraction of the small intestine to the right, and lifting the colon with the omentum upwards. You also have access to the posterior abdominal wall with the main vessels. The dotted line represents the incision for exploration and control of the left renal artery and alternative vein (ill. 20).

13



13 **The transverse colon** may also be explored by splitting the gastrocolic ligamentum – the part of the omentum located between the colon and the stomach. Clamp and ligate the ligamentum stepwise (the technical procedure in detail: p. 378). Explore the posterior side of the transverse colon, stomach and pancreas (ill. 18).

14

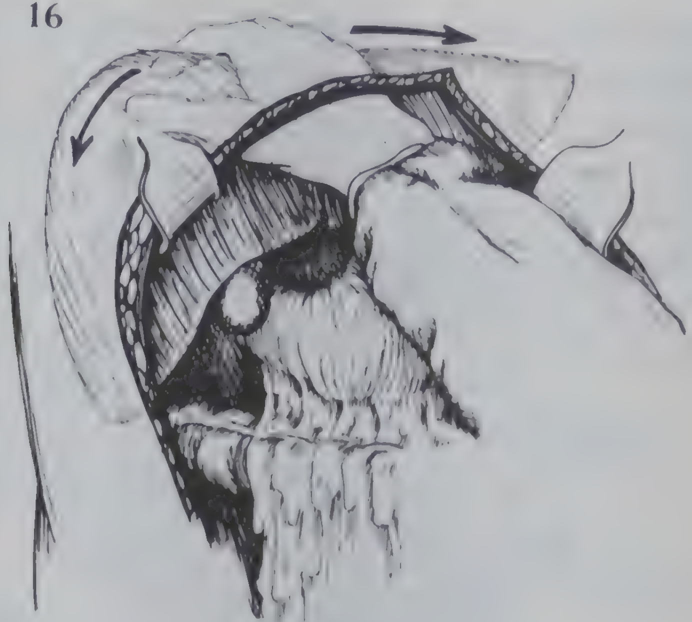


14 **The left colon, the left kidney and ureter:** Retract the small intestine to the right or out of the abdomen. Examine the left colon, sigmoid and rectum. In case of swelling or hematoma on the posterior abdominal wall, do not hesitate to mobilize the colon: Incise the peritoneum in the bloodless field lateral to the colon and mobilize the colon off the posterior abdominal wall by blunt dissection. This is also the standard access to the left kidney.

15

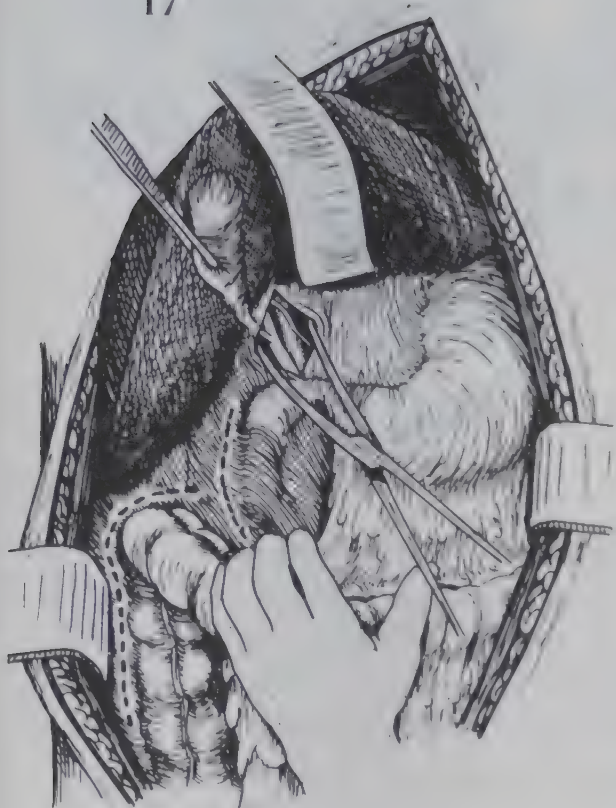
15 **Rectum and the rectovesical pouch:** For exploration of the retroperitoneal part of the rectum, ureters and bladder, incise the peritoneum in the rectovesical (female: rectovaginal) pouch. With careful traction on the rectum, it is mobilized upwards from the pelvic cavity by blunt dissection. **Notice:** In major pelvic hematomas, do not enter the hematoma without first taking control of the main proximal vessel (the iliac artery or aorta) – the bleeding may be heavy once the peritoneum is opened.

16



16 The liver: Examine the right part of the diaphragm and search carefully with your hand over the liver for tears and hematomas. **Note:** Rough manipulation of the liver may cause heavy bleeding from clotted liver wounds. Traction of the liver may cause bleeding from partial tears of the liver veins on the posterior side of the liver. The management: Pringle's maneuver (ill. 24) and 48 hours' gauze packing.

17

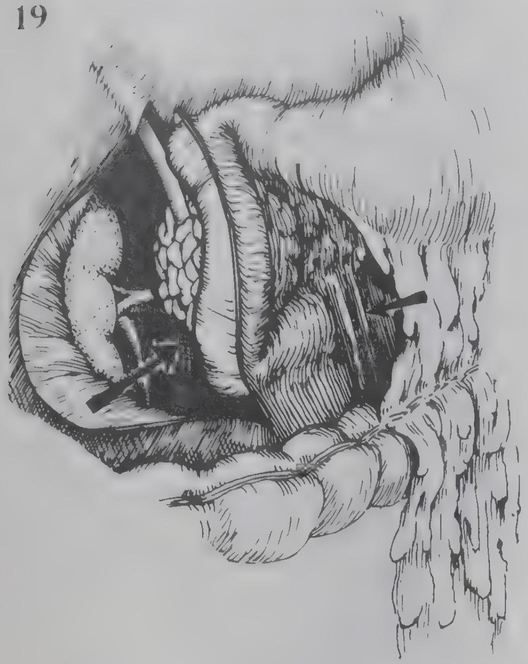


17 The liver hilum: Retract the transverse colon downwards, apply soft clamps/forceps on the gall bladder and inspect the hepatic artery, portal vein and main bile duct. They are located altogether behind the peritoneum. Hematoma, swelling, discoloration or bile leaking indicates exploration: Incise the peritoneum and identify the main structures by careful blunt dissection. The dotted lines are incisions for mobilization of duodenum (Kocher's maneuver) and the right colon (for hemicolectomy).

18

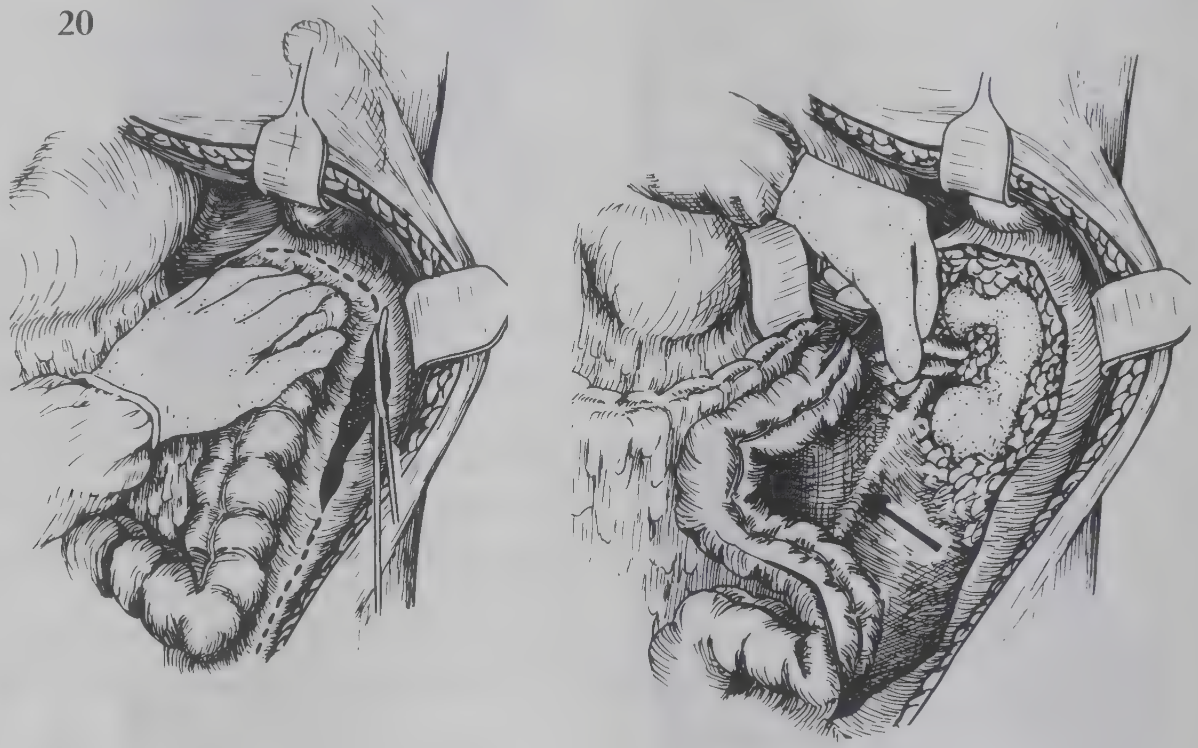
18 The stomach – proximal compression of the aorta: In upper abdominal injuries and blood on the naso-gastric tube, also the posterior side of the stomach must be explored. Split the gastro-colic ligament (ill. 13) and lift the stomach forwards. Also explore the body of pancreas, the head of pancreas is explored by Kocher's maneuver (ill. 19). **Aortic compression** is an emergency procedure done to reduce heavy abdominal bleeding: By manual compression of aorta (A) against the spine, distal bleeding vessels may be identified and controlled (p. 365). Hematomas in this area indicate tears of aorta, the caval vein (C) or the splenic artery (SA). Do not enter the hematoma without aortic clamping above the diaphragm (emergency thoracotomy: p. 154).

19



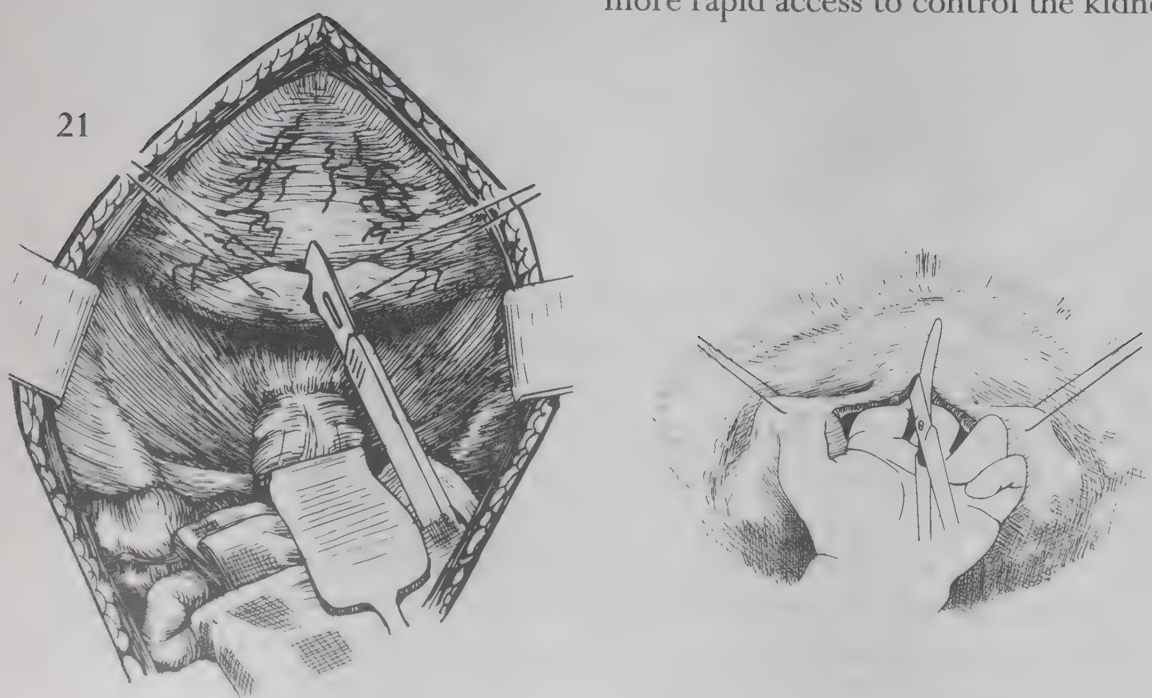
19 Duodenum – Kocher's maneuver: Retroperitoneal hematoma or swelling along the duodenum, or blood on the naso-gastric tube indicates exploration of the duodenum. Retract the transverse colon downwards, and split the peritoneum along the lateral border of the duodenum (a bloodless area). By careful soft dissection the duodenum is lifted off its bed. The bile duct running through the head of pancreas is inspected. Note the superior mesenteric artery (small arrow) carrying the blood supply to the small intestines. Also the access to the kidney vessels and the caval vein (big arrow) is excellent.

20



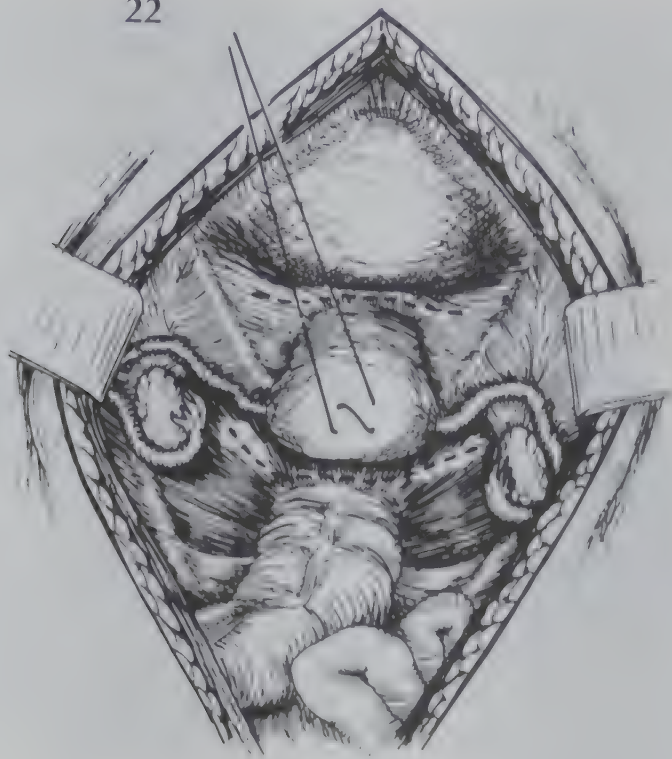
20 The spleen, the left kidney and ureter: To explore the spleen – retract the ribs upwards, the stomach towards the midline, and the left colon flexure downwards. To control the splenic artery, mobilize the spleen and expose the tail of the pancreas: Split the peritoneum lateral and proximal to the left colon flexure (the proximal part of the dotted line). Further mobilization of the left colon will expose the left kidney, the kidney vessels and ureter (arrow). A more rapid access to control the kidney vessels is the medial incision (ill. 12).

21



21 The bladder: In cases with hematuria, the bladder must be explored. This is best done from the inside: Open the bladder between two stay sutures. Monitor the function of both ureters: On a mucosal ridge some 3 cm to each side of the midline the ureters are emptying flushes of urine. Monitor each orifice until you see clear urine flowing from both ureter openings.

22



22 The female organs are easily accessible. Injuries below the peritoneum are explored by incising the peritoneum in front of the uterus or behind it in the rectovaginal pouch.

Methods to control bleeding

Remove the blood

- A metal cup or a glass is best
- You may use your hands
- In heavy bleeding, suction is not effective

Temporary control

In the dying patient: Do emergency thoracotomy with aorta clamping before the laparotomy.

- **Gauze packing:** Go for the quadrant bleeding and pack it with big gauze packs for some minutes. Proper packing will stop all bleeding – flush the transfusion and infusions. Remove the packs step by step until you identify the bleeding vessel.
- **Aortic compression:** If heavy bleeding starts at once when you remove the packing, pack again and compress the aorta. Depending upon the level of injury, the aorta is compressed below or above the mesenteric arteries. Below the mesenteric arteries the access is easy: Deliver the small intestine to the right out of the abdomen. You may split the peritoneum and clamp the aorta, or compress it with a hand against the spine. Above the mesenteric arteries: Split the gastro-colic ligament (ill. 13) and compress the aorta with one hand against the spine, the spine as close to the diaphragm as possible. **Note:** Also the back-flow in the aorta should be reduced by manual pressure just above the iliac arteries. Maintain the aortic compression steadily until the general circulation is re-established by massive transfusion/infusion. And the bleeding source is permanently under control.
- **Control the specific artery – finger clamping:** Study abdominal anatomy to know the main vascular supply to each abdominal organ. By clamping or manual compression of the main blood supply (and the vein) bleeding is re-

duced – you can identify the torn vessel and clamp it with forceps. Finger clamping is effective in kidney injury – the renal artery. Injury to the spleen – the splenic artery. Liver injury – the liver artery, the portal vein and the bile duct (Pringle's maneuver). The small intestine/right colon – the superior mesenteric artery. The left colon/rectum – the inferior mesenteric artery.

23

23 • **Tamponade for 48 hours:** Tears of the liver, of the kidneys, and minor retroperitoneal hematomas may be packed by ribbon gauze. Take the gauze through the abdominal wall by a separate stab incision. Remove it stepwise after 48 hours while you carefully monitor the circulation for signs of rebleeding. Be prepared for urgent laparotomy.

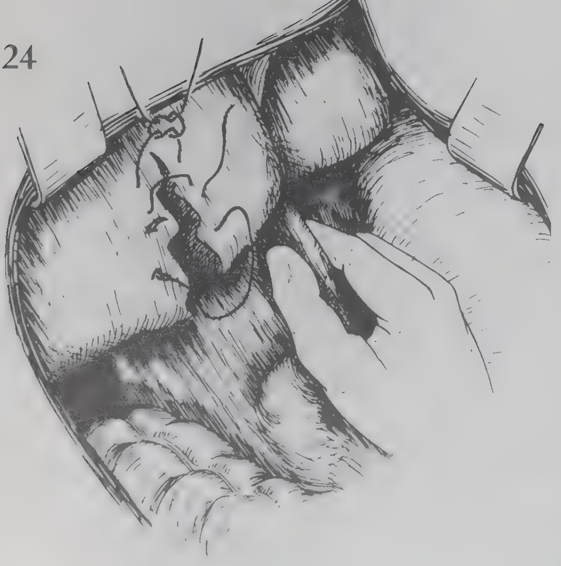
- **Two-step surgery:** If the bleeding point cannot be definitely controlled at the time of primary surgery (the one-hour limit, technical difficulties, heavy casualty load) – consider two-step surgery: Leave the gauze packing, concentrate on active basic life support – in particular, transfusions of fresh whole blood. Reoperate within 48 hours (maximum 72 hours) when the coagulation system is in order.

Types of bleeding – hands off

Some bleeding injuries are best controlled by gauze packing and conservative management. Surgical dissection and ligatures during the second operation may increase the mortality – in particular for the inexperienced surgeon. Just remove the gauze packs, mobilize the patient carefully – and hope for the best:

- **Major liver injury:** Liver resections carry higher mortality risk than do the gauze packing and conservative management. Also posterior injuries of the liver and damage to the liver veins are managed by 48 hours' packing only.
- **Kidney injury:** Even major tears may heal spontaneously without debridement, resections and suture of the capsule. The bleeding is controlled with gauze packing. At the second operation drains are applied.
- **Retroperitoneal hematomas:** Unless they are expanding, or unless the patient is dying due to the hematoma blood loss, or unless there is a retroperitoneal perforation of the intestines – the hematomas are not opened. Concentrate on optimal basic life support. **If you have to open the hematoma,** control the blood supply by compression of aorta or the local main artery before you split the peritoneum.

24



Permanent control – the technical procedures

24 **Hemostatic sutures** control superficial tears where the bleeding vessels cannot be identified and controlled by separate ligatures. Here, a large curved needle is used for inserting deep interrupted liver sutures. When all sutures are applied, they are tied. **Notice** the finger clamping of the liver artery and the portal vein (Pringle's maneuver). The vessels may also be clamped with a soft clamp. Pringle's maneuver may safely be done for 60 minutes.

25

25 Omentum for bleeding control: In most injuries of the upper abdomen, a part of the omentum may be separated, mobilized and tied inside the suture. The omentum increases the hemostatic effect.

26

26 Muscle "postage stamp" upon a bleeding surface: A piece of muscle (some abdominal muscle is convenient) is crushed between fingers to form a "postage stamp" some mm thick. The muscle is carefully pressed against the bleeding wound for some minutes, or tied to the bleeding surface by sutures. Here bleeding from the raw surface of the kidney after the debridement is managed by finger clamping of the vessels, and a muscle transplant inside the capsular suture.

Reconstruction? Ligature? Resection?

Some of the main abdominal arteries are end-arteries – ligature of the artery causes necrosis and organ death.

- **Aorta:** Only minor tears survive up to surgery, but those patients may well live for hours with few clinical signs. Reconstruction is done with direct suture or vein patch.
- **The common and the external iliac artery:** There is a rich communicating network from the opposite internal iliac artery. Young people may survive ligature without necrosis of the leg, but reconstruction should be considered.
- **The internal iliac artery:** Supply from the opposite internal iliac artery makes ligature a safe procedure.
- **The renal artery:** After ligature the kidney must be removed (nephrectomy). Reconstruction of the renal artery is seldom indicated in primary wartime surgery. In cases where you suspect kidney damage, do contrast urography before or during surgery.
- **The hepatic artery:** The liver also has blood supply from the portal vein. Young patients may survive ligature of the hepatic artery if the portal vein is not damaged. Reconstruction should be considered.
- **The splenic artery:** Ligature is followed by splenectomy.
- **The vascular supply for the stomach and duodenum:** There is a rich communicating network – ligature is safe. Resections after ligature are seldom indicated.
- **The mesenteric arteries:** There is some collateral circulation, but ligature of the main branches often causes necrosis of parts of the intestine. Take your time during the operation to observe the local circulation after the ligature is applied. If you are in doubt: Resection with double enterostomy of the intestinal ends is a simple and safe procedure. After minor resections of the small intestine, end-to-end anastomosis is done at the time of resection.

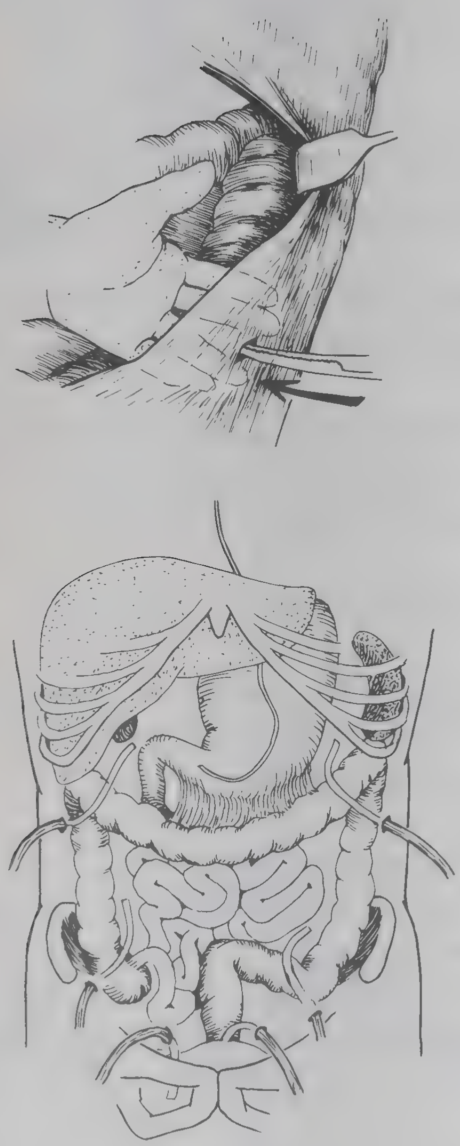
Fresh whole blood: p. 268.

"False" control
If the patient is hypovolemic during surgery, the bleeding control may be deceptive. When the circulation is restored after proper volume therapy, the bleeding may start again:
- Always monitor the serious abdominal cases closely while the circulating volume is re-established.
- Be prepared for another urgent laparotomy.
- The best preventive measure: transfusions of fresh whole blood rich in platelets.

Decompression – drainage – closure

This is a three-in-one routine procedure: Gastric tube decompression and dependent drainage by double abdominal tube drains are always arranged before the midline incision is closed. There is only one exception: When the abdomen is gauze packed during emergency laparotomy, abdominal drainage is not done.

27



27 Drainage of the abdominal cavity: Dependent tube drainage is more effective (and less expensive) than the small-caliber suction drains. Small-caliber drains may clot (blood or pus). Also the drain may become obstructed by the omentum or loops of the intestine: Use two drains, minimum 10 mm wide. You may use any plastic tube not too soft, cut side holes in it. Make a small stab incision through the far lateral abdominal wall for the tube. Consider the gravity in order to achieve effective drainage: The patient should for eg. be half-sitting to drain the lower part of the abdomen. Or put him in a half-side position at intervals to improve the drainage. Early respiratory exercises and effective analgesia improve the drainage. There are many pockets where blood, bile or urine may collect and give rise to secondary infection. Illustrated is the standard drainage of the four abdominal quadrants. In addition drainage should be done close to intestinal sutures and anastomosis. Make sure that the drain does not damage the suture line. Also note the extraperitoneal drain lateral to the bladder in pelvic injury.

Decompression of the gastro-intestinal tract
The tract is paralytic for some days after injury and surgery. Fluids and gas will collect inside the intestines and stomach. To relieve the patient, the intestinal sutures and the midline incision suture, decompression must always be done for 48-72 hours after the laparotomy – there are no exceptions to this rule. Either insert a naso-gastric or naso-duodenal tube guided by the hand during surgery. In major injuries, multiple-injury cases and other cases carrying a high risk of secondary complications, do a tube gastrostomy for both decompression and enteral feeding.

28

28 Decompression and nutrition by tube gastrostomy: Insert a large-bore Foley catheter through a stab incision in the abdominal wall and into the stomach. The small stomach incision is closed by a circular suture and the catheter balloon is inflated. Some sutures between the stomach serosa and peritoneum will fix the stomach to the abdominal wall. During a few days adhesions will form to secure the fixation. Tape the catheter over a roll of gauze under slight traction. In most cases catheter feeding can start the first post-operative day.

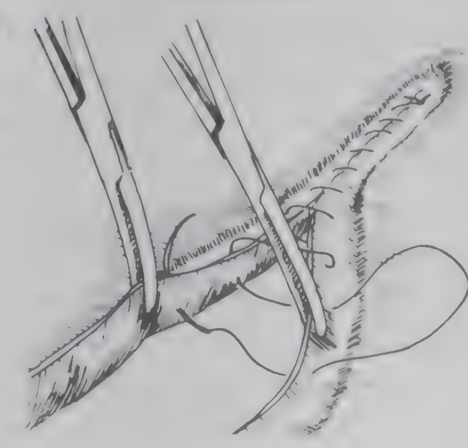
Closure of the midline incision

Before closure: Are you sure no instruments or gauze packs are left inside? Count, and compare with the list made up before surgery.

The incision may be closed layer by layer with separate absorbable sutures for the peritoneum, for the abdominal wall and non-absorbable for the skin. Or it may be closed all in one layer by strong interrupted nylon or silk sutures.

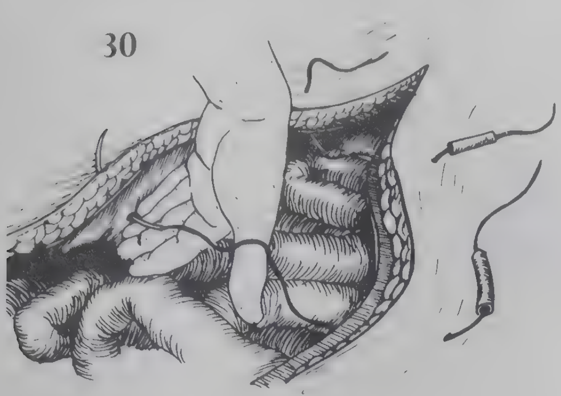
In emergency two-step surgery: towel clamps may be used for temporary closure of the midline incision to reduce the operation time.

29



29 Closure of the midline incision: Grasp the peritoneal edge with clamps and close the peritoneum by continuous over-and-over sutures (absorbable 3-0). Take care not to tie up any intestinal loops. Close the muscle fascia with cross-wise strong sutures (no 1, absorbable or silk). Then close the skin.

30



30 Relief sutures: To relieve tension in the suture line and to reduce the risk of wound infection and rupture, a few sutures (no 1 or 2) are inserted 5-7 cm from the incision before you close the incision. Tie the relief sutures in rubber tubes to avoid pressure sores on the skin. Also some broad bands of adhesive plaster across the dressing will relieve tension upon the midline suture. If the abdomen is distended (bleeding/gauze packs), split plastic infusion bags may be interposed in the midline incision.

Emergency laparotomy

Emergency laparotomy
- is done on dying patients
- is life saving
- should be done there and then

Emergency laparotomy is done
- with few and simple surgical instruments
- in the field
- under intermittent i.v. ketamine anesthesia
- by any paramedic trained in the procedure

Long evacuation: Consider field laparotomy.

Reasons to do emergency laparotomy

Grave circulatory shock
No response to volume therapy
↓
Emergency thoracotomy
Aorta compression/clamping
↓
Emergency laparotomy

Circulatory unstable
Long evacuation → Emergency laparotomy
↓
Urgent laparotomy

Circulatory stable
↓
Peritoneal lavage?
X-ray?
Laboratory examination?
↓
Consider laparotomy

Preparations

- Basic life support: Establish free airway and effective respiration before the laparotomy is done.
- Control external bleeding (compression): Most major abdominal cases have multiple injuries.
- Volume therapy: Venous cut-down or central venous catheter to establish two large-caliber i.v. lines. Flush the infusions/transfusions.
- Cases with hemodilution after fluid infusions: Blood transfusion is as important as surgery. Start with O blood; try to get fresh whole blood.
- Instruments: Small general surgical set. Metal cup or a glass for removal of blood. Gauze packs 30x30 cm. There is no time for sterilization or sterile washing.
- Antibiotics: High i.v. dose before and during surgery.
- Anesthesia: Start with i.v. ketamine anesthesia. Consider supplement with general anesthesia when the bleeding is under control. Be prepared for total circulatory collapse when the abdomen is opened.

The procedure

Observe the one-hour limit in unstable cases
What cannot be done inside the abdomen by a trained operator within 60 minutes, should probably not be attempted at all.

First control bleeding

- Consider emergency thoracotomy with aortic compression/clamping in dying patients.
- Midline incision from sternum to below the umbilicus.
- Heavy bleeding: Go directly for the aorta above the mesenteric arteries and compress it with a hand. Also compress/clamp the aorta immediately above the iliac arteries.
- Go directly for the quadrant bleeding: Remove blood, and pack with large gauze packs. Apply manual pressure upon the packs for 10 minutes.
- Autotransfusion may be life saving. In cases without colon injury, with only minor small intestinal injury: Collect the blood from abdomen for autotransfusion.

Bleeding tears of solid organs may be tamponed separately: p. 394.

Then close intestinal perforations. Also regarding the intestinal viability, it is more important to restore the circulation than to close intestinal wounds. Do not exceed the one-hour limit: You may stop the fecal stream by tying gauze bands proximal and distal to the perforations. Or leave the perforations open inside the gauze packs. If there is time for it do the following:

- Minor colon wounds and all wounds of the right colon: Suture and diversion loop-enterostomy.
- Major wounds of the transverse and left colon: Take the wound out as colostomy. Or make resection and two separate end-colostomies.
- Minor wounds of the small intestine: Suture.
- Major injury to the small intestine:Take the wound out as enterostomy, or make resection and end-to-end anastomosis.

Leave all other organs without repair. Close the midline incision with all-in-one interrupted sutures and relief sutures. Monitor the circulation closely – be prepared for another urgent laparotomy. Continue intensive antibiotic therapy. Make a planned laparotomy with definitive repair within maximum 72 hours.

Points to note – Chapter 27

Know when to do laparotomy

- control of bleeding has first priority: p.156 and 356
- closing intestinal wounds has second priority, but there are time limits: p. 380

Study the anatomy

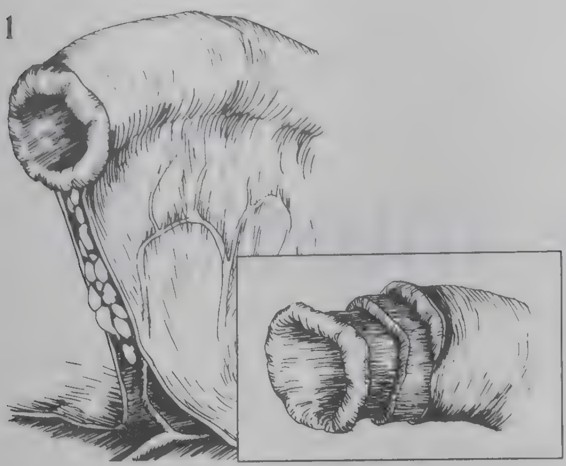
- note the localization of the superior and inferior mesenteric arteries: p. 376. Also see p. 401
- note the compartments along the rectum: p. 376. They must be drained in rectal injuries: p. 387
- note the risk of intestinal injuries in penetrating pelvic injury: p. 469

Learn the technique of diversion enterostomies

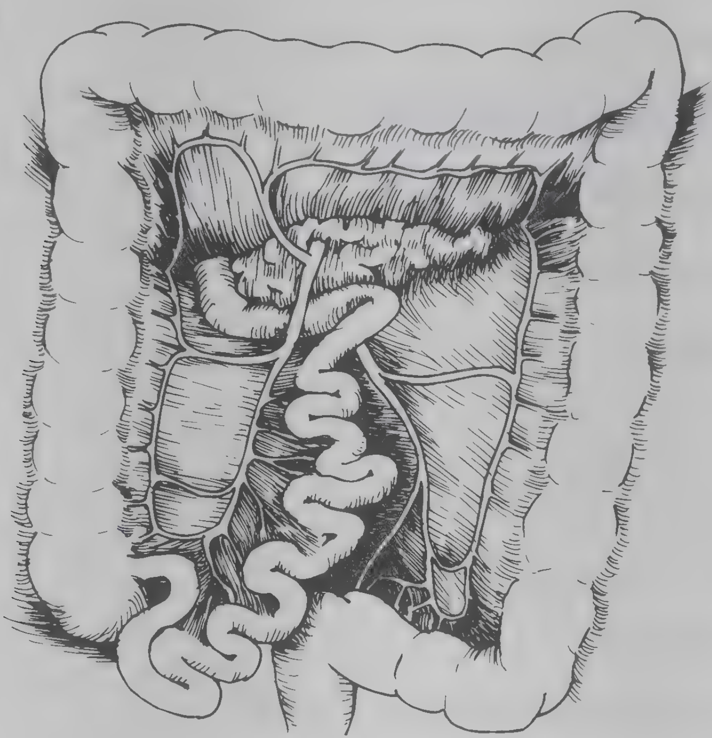
- know the different types of enterostomy: p. 378
- the ileostomy: p. 382
- the colostomy: p. 384 and 385
- note the special problems of injuries to the right colon: p. 385
- know the common complications after enterostomy: p. 463

27 Injury to the intestine

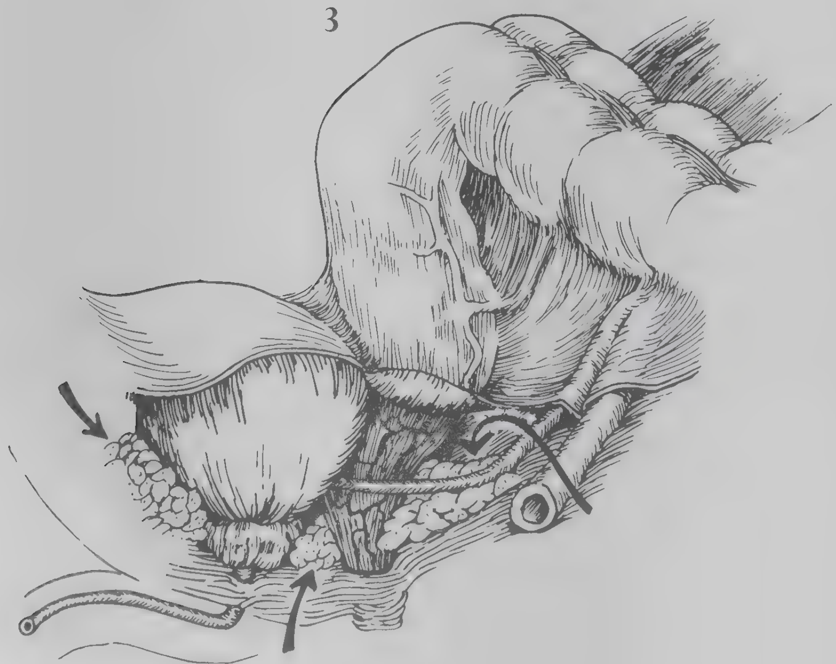
Surgical anatomy

1


1 The structure of the intestine: The small intestine, the transverse and sigmoid colon are indirectly attached to the posterior abdominal wall through a mesentery. The mesentery is covered by peritoneum, and contains fat and the vascular supply to the intestine. The vascular network in the mesentery is rich in collaterals and may endure moderate injuries without necrosis of the intestine. The duodenum and large intestine are far more vulnerable to vascular injury. The wall consists of three layers. From inside out: the mucosa, the muscular layer and the serosa. The intestinal sutures should include all three layers.

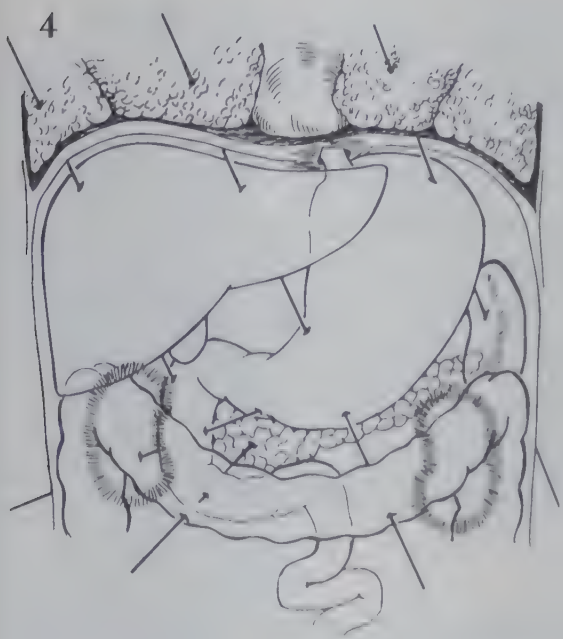
2


2 The blood supply for the intestine: The superior mesenteric artery runs through the body of pancreas in front of the duodenum and supplies the small intestine, the right colon and the transverse colon. **The inferior mesenteric artery** runs behind and below the duodenum and supplies the left colon, sigmoid and rectum. Ligature of the main branches of these arteries will invariably create hypoxia/necrosis of parts of the intestine: Intestinal resection is necessary.

3


3 Anatomy of the rectum: The blood supply is rich; there are collaterals from the internal iliac artery, and the rectal tears normally heal well. The main problem is hematoma and abscess formation in the spaces of fat and loose connective tissue inside the pelvic cavity (arrows). Effective drainage is essential. Note the close relationship to the bladder: Hematuria indicates exploration and suprapubic drainage of the bladder.

4



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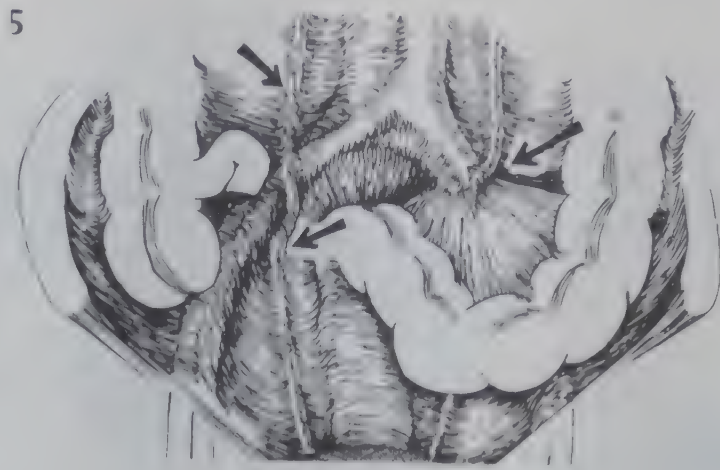


4 Associated injuries are common in high colon injury. Note the close relations in the upper abdomen. Study the procedures for exploration: p. 361.

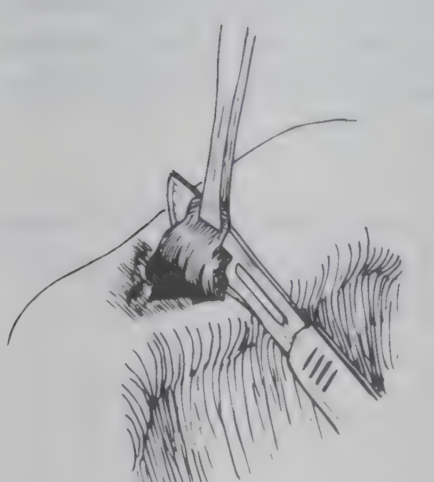
5 Associated injuries: Note the close relationship between the colon and the ureters and the iliac arteries both on the left and right side. Many injuries to the ureter are made by careless surgery. Do not mobilize the right or left colon unless you first identify the ureter.

The general procedure in missile injury

- **The small intestine** contains fluids with low bacterial content. After perforations peritonitis develops slowly. Perforations normally heal well after suture.
- **The duodenum, the distal ileum and the right colon:** The intestinal contents are irritating to the tissues. Intestinal sutures may rupture. There are often skin problems around ileostomies and colostomies of the right colon.
- **The colon and rectum:** The bacterial content is high. Peritonitis develops soon after the perforation (unless the injury is retroperitoneal – p. 361). The risk of rupture of the suture line and post-operative peritonitis is high.

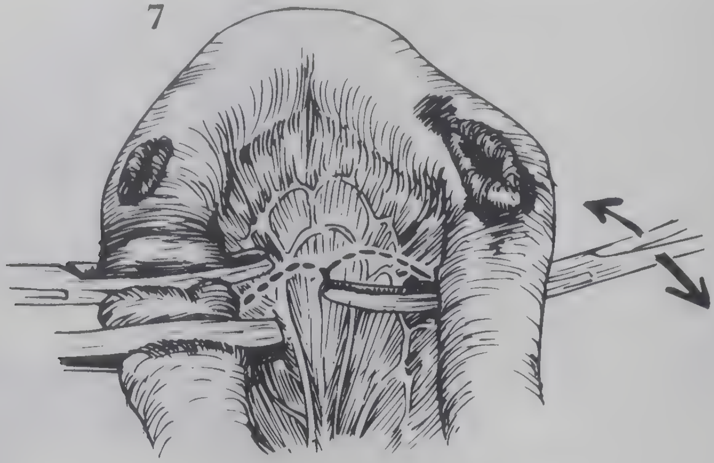
Debride the intestinal wound

6



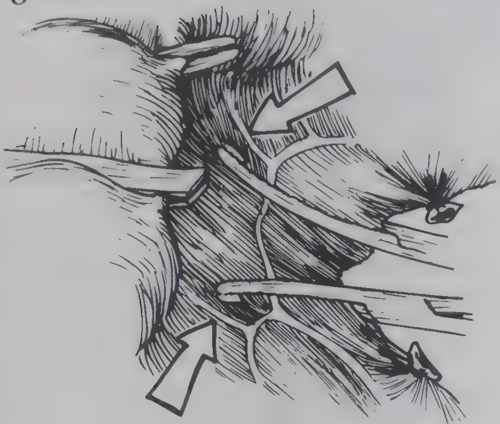
6 Debride for transverse suture: The well-vascularized intestine is pink and not swollen. Tiny wounds of the small intestine may be sutured without debridement. But never apply sutures through a cyanotic, dark red or swollen intestinal wall: That suture will rupture. Excise the wound edges to form a transverse incision (p. 381). The bleeding from mucosa will stop when the intestine is sutured.

7



7 Resection may be the best debridement: Major tears or double perforations through a loop or flexure are managed by resection and end-to-end anastomosis. Hematoma in the mesentery: Examine carefully the circulation of that part of the intestine. If in doubt, do resection-anastomosis: Clamp the intestine with soft intestinal clamps. Do stepwise ligature of the mesentery along the dotted line.

8

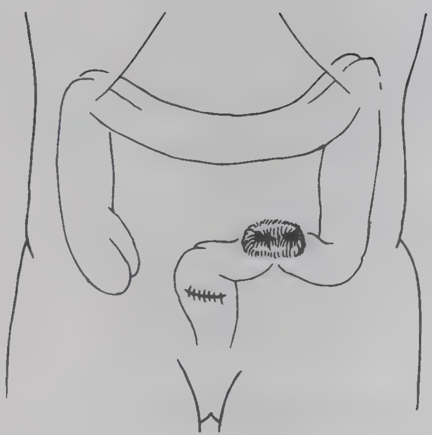


8 Spare the vessels to the anastomosis: Inspect the cut ends of the intestine to see if they are well vascularized. Change the knife blade after cutting the intestine.

Diversion enterostomy to protect the suture

By an enterostomy proximal to the injury, the intestinal content is diverted from the wounded intestinal area. The pressure upon the suture line is reduced. There is less risk of rupture at the suture line. The enterostomy may be reversed and the stoma closed after 2-6 weeks if the bowel function is normal.

9



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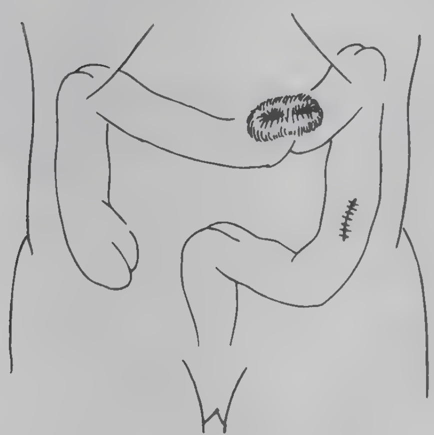
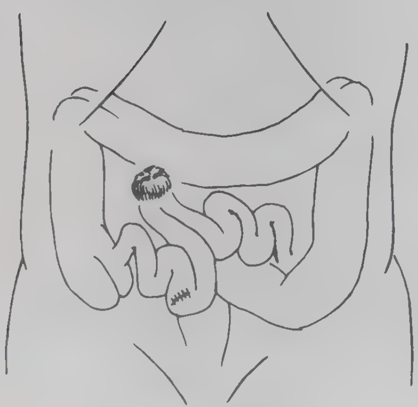


9 Diversion enterostomy in rectal injury: The injury is debrided and sutured. The sigmoid colon is used for enterostomy.

10 Injury to the left colon: The transverse colon is used for enterostomy.

11



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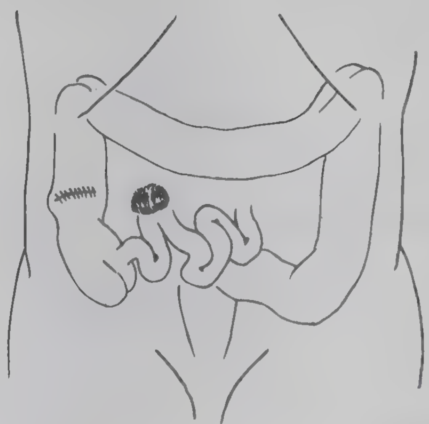


11 Injury to the right colon: The distal ileum is used for enterostomy. **Note:** There are particular problems associated with injuries to the right colon (p. 385).

12 Injury to the ileum: A loop of ileum just proximal to the injury is used for enterostomy.

Decompress the intestines

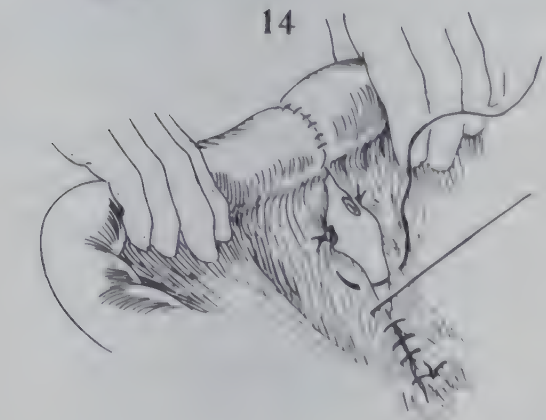
- **Naso-gastric tube** is inserted before surgery. Before you close the laparotomy, guide the tube into the duodenum and start suction. Continue intermittent suction for 2-4 days until the bowel function restarts.
- **Dilatation of the anus** is done in sigmoid and rectal tears to prevent retention of fluid inside the intestine.

13

Close incisions in the peritoneum and mesentery

13 The peritoneal suture: If you have incised the peritoneum during exploration and mobilization of abdominal organs, close these incisions before you close the abdomen. If not intestinal loops may adhere and become fixed to the raw surface. In this case the peritoneum is closed by a continuous over-and-over suture after mobilization of the left colon. The suture materials: absorbable or silk 3-0 or 4-0.

14



14 Close incisions in the mesentery: Otherwise the small gut may slip through the incision, become strangulated and create an intestinal obstruction.

Drain and monitor the suture line

Rupture of the intestinal suture will in most cases happen between the 4th and 8th day after surgery. Apply a dependent tube drain in the area of intestinal sutures. Monitor that drain closely during the risky period: Increased drainage production with fecal smell indicates wound rupture and urgent relaparotomy.

The standard procedures are safe, the alternatives are risky

In mass casualties and in cases left without proper post-operative monitoring you should stick to the standard procedures. But they are time consuming, and certain exceptions should be considered:

- **Emergency laparotomy:** The objective is to gauze pack the abdomen, control bleeding and save life. In serious cases, intestinal tears may be tied or left unmanaged for 24 hours, and all efforts concentrated to prevent death in circulatory shock (see below).
- **Jejunum:** In stable cases, small single wounds may be debrided and sutured without doing a proximal enterostomy. In that case decompression by gastric tube suction is mandatory.
- **The right colon:** With proper facilities for monitoring, minor perforations may be closed without enterostomy if the local blood supply is good and surgery is done within four hours after the injury.

The emergency laparotomy in detail: p. 155.

Two-step management in emergencies

Early and late mortality – two risk factors

- **Early death due to bleeding:** The intestinal injury itself seldom bleeds much, but associated bleeding injuries are common. The first priority is to

prevent death from bleeding. That should be done within a one-hour emergency laparotomy. Then the abdomen should be closed – and re-explored with organ repair after 24-48 hours.

- **Late death due to peritonitis:** Peritonitis after abdominal injury carries a high risk of secondary organ failure and late death. The risk of post-operative peritonitis is a question of proper and early management of the intestinal damage. But the two objectives of bleeding control and intestinal repair may come into conflict: If the bleeding and the intestinal injury cannot both be managed within one hour, the intestinal injury should be left for secondary repair. The main point in primary surgery is to prevent death from bleeding. The risk of peritonitis in multi-organ injuries is anyhow high due to poor organ blood perfusion.

There are thus two types of emergency procedures in intestinal injuries:

- **Regarding the first-phase mortality: Do emergency laparotomy to control heavy bleeding.** Bleeding is controlled by aortic compression and gauze packing. The intestines and other intraperitoneal organs are explored to identify the injuries, the damage is carefully registered in the Patient Chart, but the repair is delayed. Within one hour's surgery the midline incision should be closed. In this phase of the management, the objective is to restore the blood perfusion of the abdominal organs as soon as possible: Within one hour after surgery the circulatory shock should be managed, the hematocrit restored at approximately 20, and the hemoglobin level restored (8 g/100 ml). If the perforations of the large intestine can be closed by a one-layer continuous suture within the one-hour surgery, do so. The fecal stream may also be stopped by simply closing the intestine with tied gauze bands proximal and distal to the injury. Or the intestinal injury left unmanaged inside the gauze pack. High dose i.v. antibiotic therapy is essential.
- **Regarding the second-phase mortality: Do emergency laparotomy to divert the fecal stream before a long evacuation.** In a stable case with evident intestinal injury (signs of peritonitis, evisceration), a diversion enterostomy and gastric tube decompression should be done in the field if definitive surgery cannot be done within 12 hours. The reason may be long evacuation, heavy military pressure or high load of casualties. Either the intestinal perforation is brought out of the abdominal cavity as a stoma (p. 384) or a loop-enterostomy is done using uninjured intestine proximal to the injury. The quadrant with the intestinal perforation is gauze packed. The enterostomy is done through a small midline incision under i.v. ketamine anesthesia. For trained staff the complete procedure is done within 30 minutes.

Loop-enterostomy:
– of the small intestine: p. 382
– of the colon: p. 384

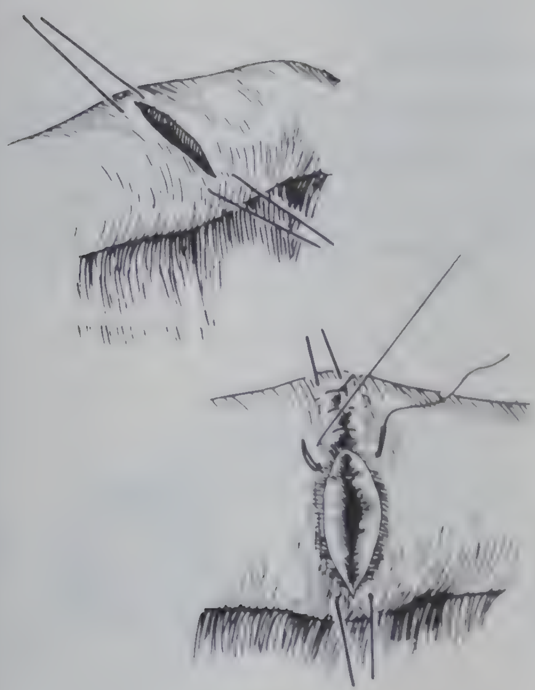
> Train your forward staff – paramedics and doctors – in the emergency procedures:
> - Loop-ileostomy
> - Transversostomy
> - Sigmoidostomy
> - Gauze packing
>
> The procedures are life saving only when done early, maybe, in the field.

Injury to the small intestine

Penetrating abdominal injuries:
- Nine out of ten cases have perforations of the small intestine
- Multiple perforations, three to five per case, are common
- Injuries to the small intestine do not bleed much. Also mesenteric vascular bleeding normally stops spontaneously

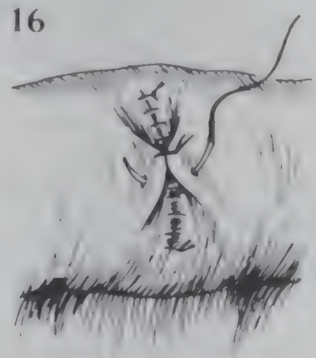
The risk of wound rupture increases when you move from the direction of colon towards the duodenum. Very proximal jejunal tears are managed just as for the duodenal injuries (p. 402).

15



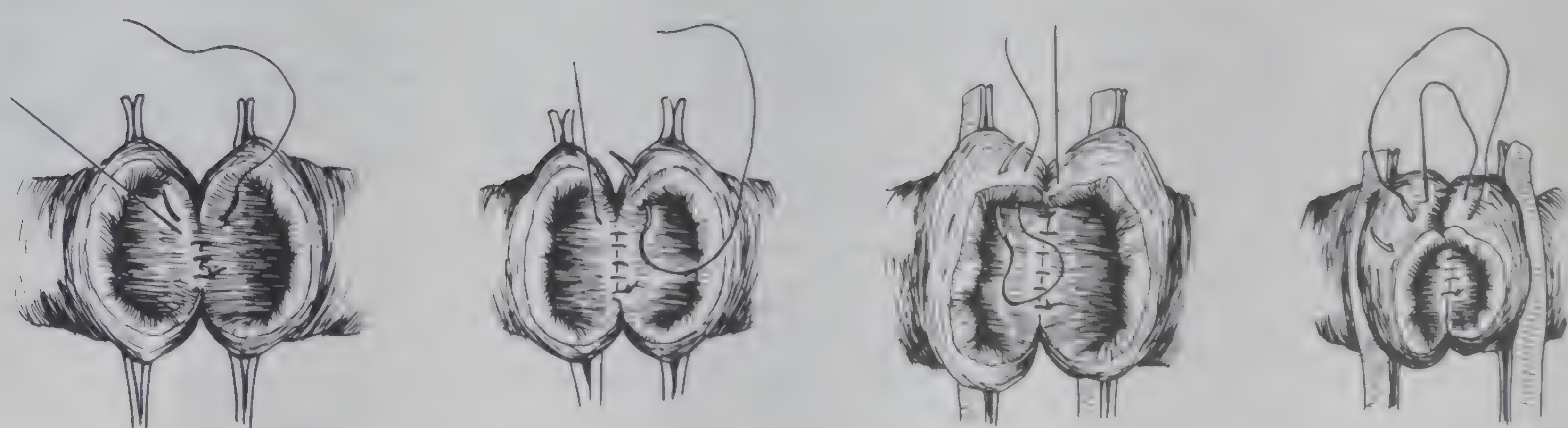
15 The suture technique: A one-layer continuous over-and-over suture is illustrated (absorbable or silk 3-0 or 4-0). You may also use two-layer suture. Each suture must include all three layers of the intestinal wall. See to it that the wound edges are well invaginated into the intestine all the way in the suture line. The longitudinal wound is transformed into a transverse one using stay sutures. Longitudinal sutures cause narrowing of the intestine, increased pressure on the sutures, and rupture of the suture line.

16



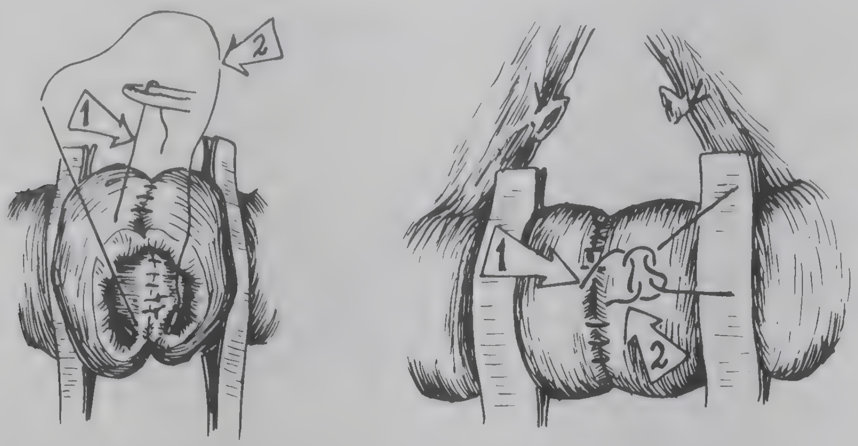
16 Serosal sutures: If you doubt the patency of your suture, apply interrupted sutures from serosa to serosa to invaginate the primary suture line. Or catch a tag of the omentum and fix it with some serosa sutures to cover the suture line.

17



17 End-to-end anastomosis – suture no. 1: Is the blood circulation of the intestine ends sufficient? Let your assistant approximate the clamped intestine ends. Suture no.1 starts at the midline with continuous over-and-over sutures. Invaginate each suture carefully at the corners, where the rupture tends to occur. Continue the suture to the midline. **Note the sutures at the front:** They are not over-and-over. Make sure that each suture takes all three layers of the intestine.

18



18 End-to-end anastomosis – suture no. 2: Start at the midline, and repeat the procedure from inside the intestine towards the opposite side. Let sutures no. 1 and 2 meet at the front and tie them. Control the patency of the anastomosis with your fingers: The anastomosis should admit your thumb.

Injury to the distal small intestine – ileum

End-ileostomy: ill. 30.

In most cases injuries of the small intestine may be closed without enterostomy. In cases late for surgery, patients in prolonged circulatory shock and those with multiple intestinal tears – enterostomy is indicated. In that case use the first normal, uninjured intestinal loop proximal to the anastomosis for enterostomy.

19

20

19 Prepare the loop-ileostomy/jejunostomy: Make a separate incision 7-8 cm wide just lateral to the rectus muscle. Control bleeding inside the incision, pull the intestinal loop through the incision, and secure its position with some forceps, etc. Check with your finger that the intestine is not strangulated in the incision. Fix the loop to the abdominal skin with some interrupted serosal sutures. Now finish your surgery inside the abdominal cavity and close the midline incision before you proceed with the enterostomy.

20 Open the loop-enterostomy: Cover the midline incision and the stoma incision with gauze packs before you open the intestinal loop with a transverse knife incision. Use suction to avoid intestinal contents contaminating the wound. Interrupted all-layer sutures fix the intestine to the skin.

Injury to the proximal small intestine – jejunum

- **Jejunal injuries in general:** You cannot use diversion enterostomy to relieve the anastomosis. Instead insert a naso-gastric tube during the operation. Guide the tube down into his duodenum and apply suction there and then. Continue with intermittent suction for 2-4 days until his intestinal function returns spontaneously.

- **Jejunal injury close to the duodenum:** Manage as for the duodenal injuries (p. 402).

Intestines outside the abdomen – evisceration

The evisceration normally consists of necrotic or perforated loops of the small intestine. Do not let them slip into the abdomen: Insert a plastic rod or a clamp through the mesentery and leave the loops outside the abdominal wall as enterostomy until definitive surgery can be done. Necrotic loops may be resected in the field and double end-ileostomies fixed in the inlet wound/incision.

Injury to the colon

The contents of the large intestine create peritonitis
- Empty the intestine with suction through intestinal tears, and close the tears with clamps at once when you locate them during the exploration.
- Cover the operating field around the perforations with gauze packs to avoid contamination inside the abdominal cavity.
- Throw away knife blades and other instruments contaminated with intestinal contents, before you close the intestine or start surgery on other abdominal structures.

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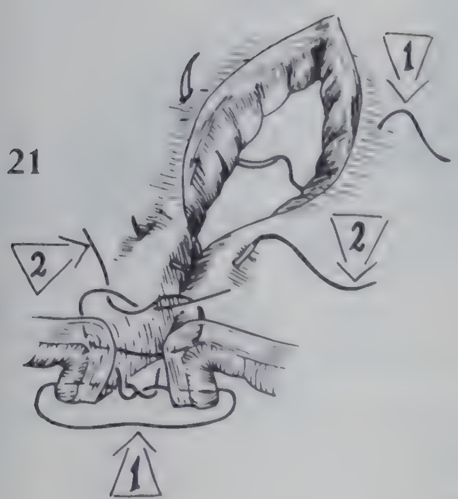

21 The two-layer suture technique: The inner suture (1) is continuous and includes all three layers of the intestine. The outer layer (2) is interrupted and includes just the serosa. This is the standard procedure for closure of wounds to the large intestine, except for distal tears of the rectum.

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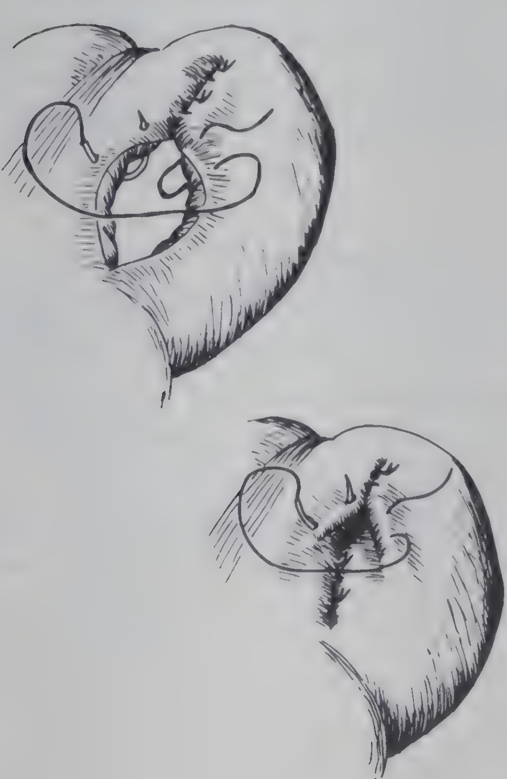


22 A small wound may be sutured longitudinally, while major wounds are closed by transverse sutures (ill. 15). Use a small curved needle (absorbable or silk 3-0) and apply the inner layer of continuous or interrupted invaginating sutures. The outer suture (3-0) is interrupted and includes only the serosa. Tags of the omentum fixed to the serosal sutures help protect the suture line.

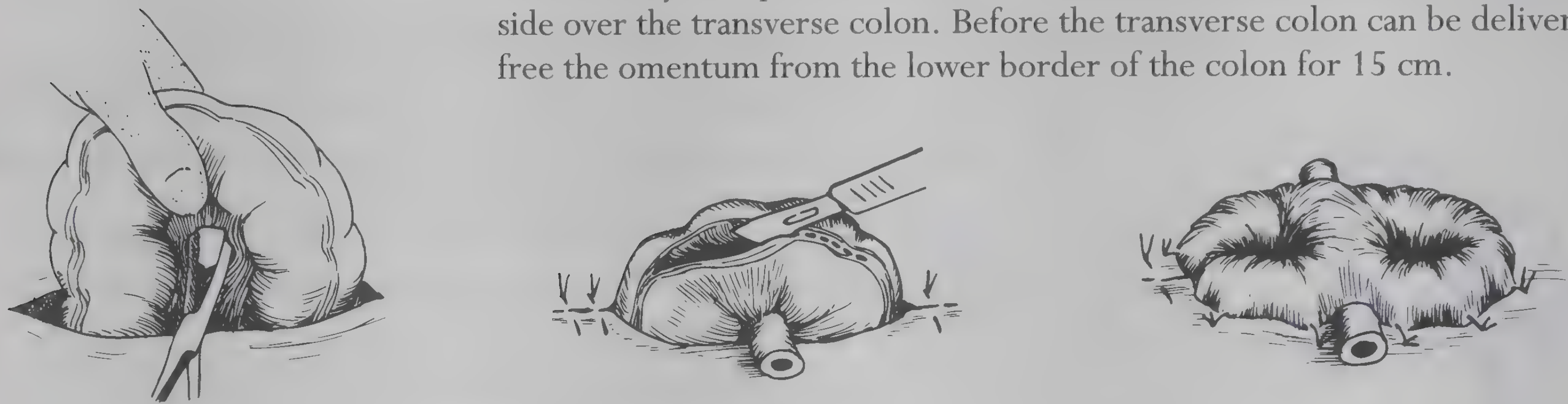
Three methods for primary management
- Method one – suture and diversion enterostomy. Indication: rectal injuries and minor injuries of the colon
- Method two – use the perforation as enterostomy. Indication: cases that cannot tolerate extensive surgery
- Method three – resection and double end-enterostomy. Indication: major injuries.

The right colon: There are particular problems and particular management procedures (p . 385).

23

23 Method 1 – suture the wound and do a proximal diversion colostomy: The perforation is debrided and closed (two-layer suture). In this case with a left transverse colon perforation, the right transverse colon is used for enterostomy. A separate incision for the colostomy is made on the right-hand side over the transverse colon. Before the transverse colon can be delivered, free the omentum from the lower border of the colon for 15 cm.

24

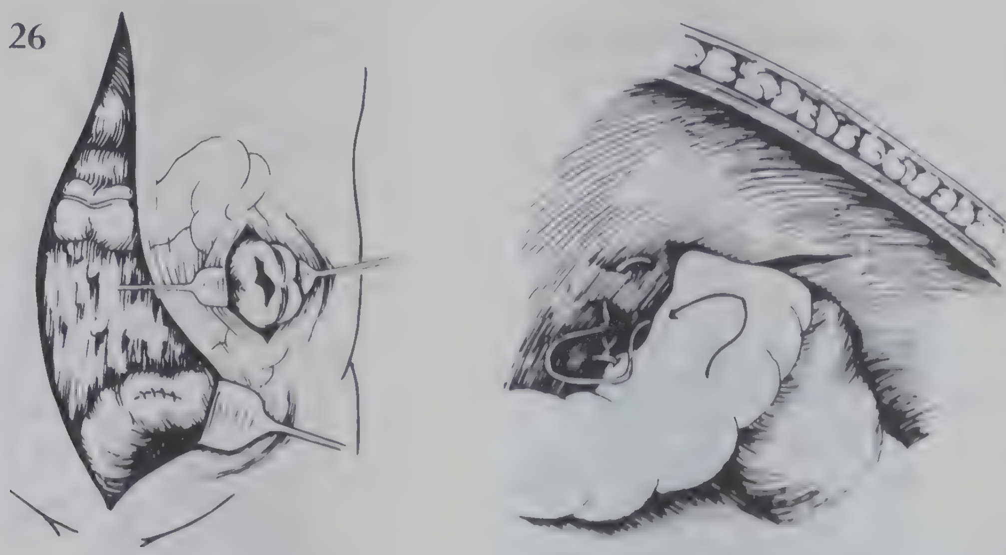


24 The loop-colostomy: The transverse colon is delivered through the incision and fixed over a rod of plastic or a stiff rubber drain. Check that the colon is not under tension through the incision. The right and left colon has to be mobilized from the posterior abdominal wall to be delivered for colostomy (p. 361): A colostomy under tension invariably causes complications (p. 463). Close the enterostomy incision, but do not open the colostomy until the midline incision is closed. Then incise the enterostomy along one of the white fibrous bands to reduce bleeding. Fix the edges of the colon to the skin with interrupted sutures at short intervals.

25

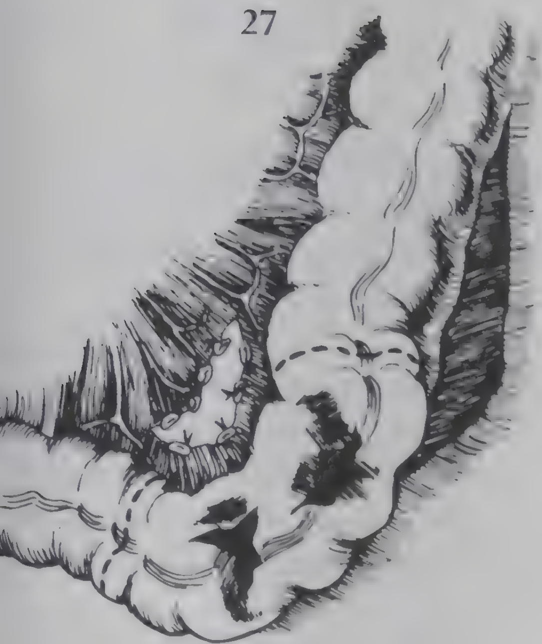
25 Method 2 – deliver the perforation itself as enterostomy: The method is particularly suited to injuries of the transverse and sigmoid colon. The injured segment of the intestine is delivered through a separate incision and fixed over a rod. When the midline incision is closed, the enterostomy is completed.

26



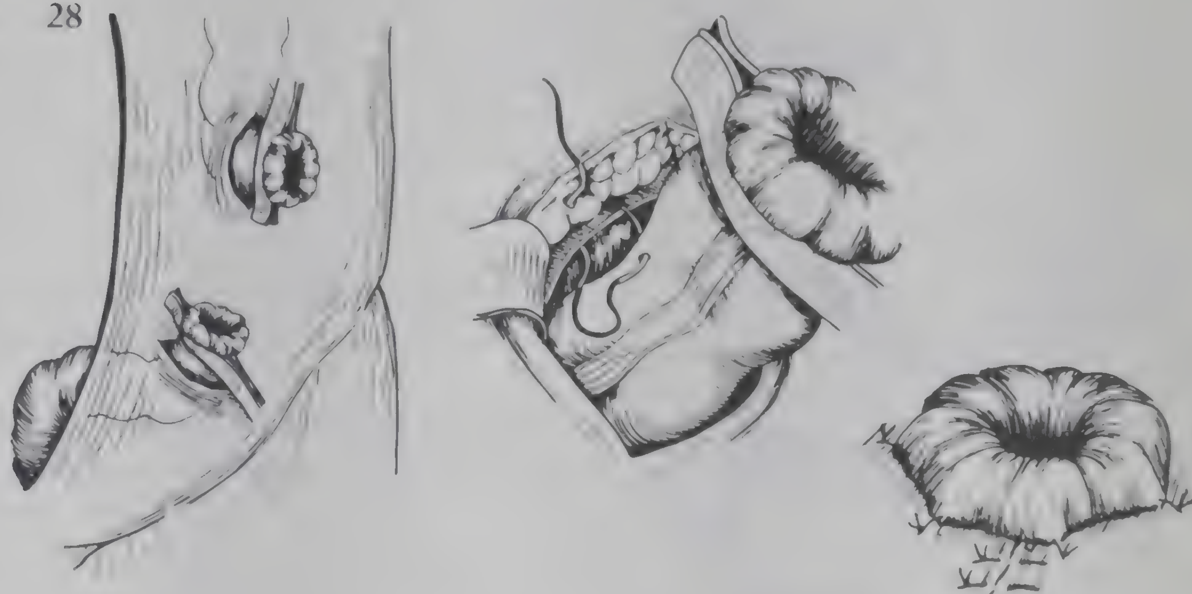
26 A combinations of methods 1 and 2 is indicated in multiple injuries of the colon. Debride and close the distal perforations (method 1), in this case a sigmoid tear. Deliver the proximal perforation as enterostomy (method 2), in this case a left colon tear. **Note:** Close the space between the enterostomy and the lateral abdominal wall with some interrupted sutures to prevent entrapment of the small intestine.

27



27 Method 3 – resection and double end-enterostomy: The method is fit for high-energy injuries with extensive intestinal tears. In this case the distal left colon and the sigmoid is mobilized by a peritoneal incision lateral to the left colon, and isolated with soft clamps at the (dotted) line of resection. The sigmoid mesentery carrying the vascular supply to the damaged section is ligated stepwise.

28

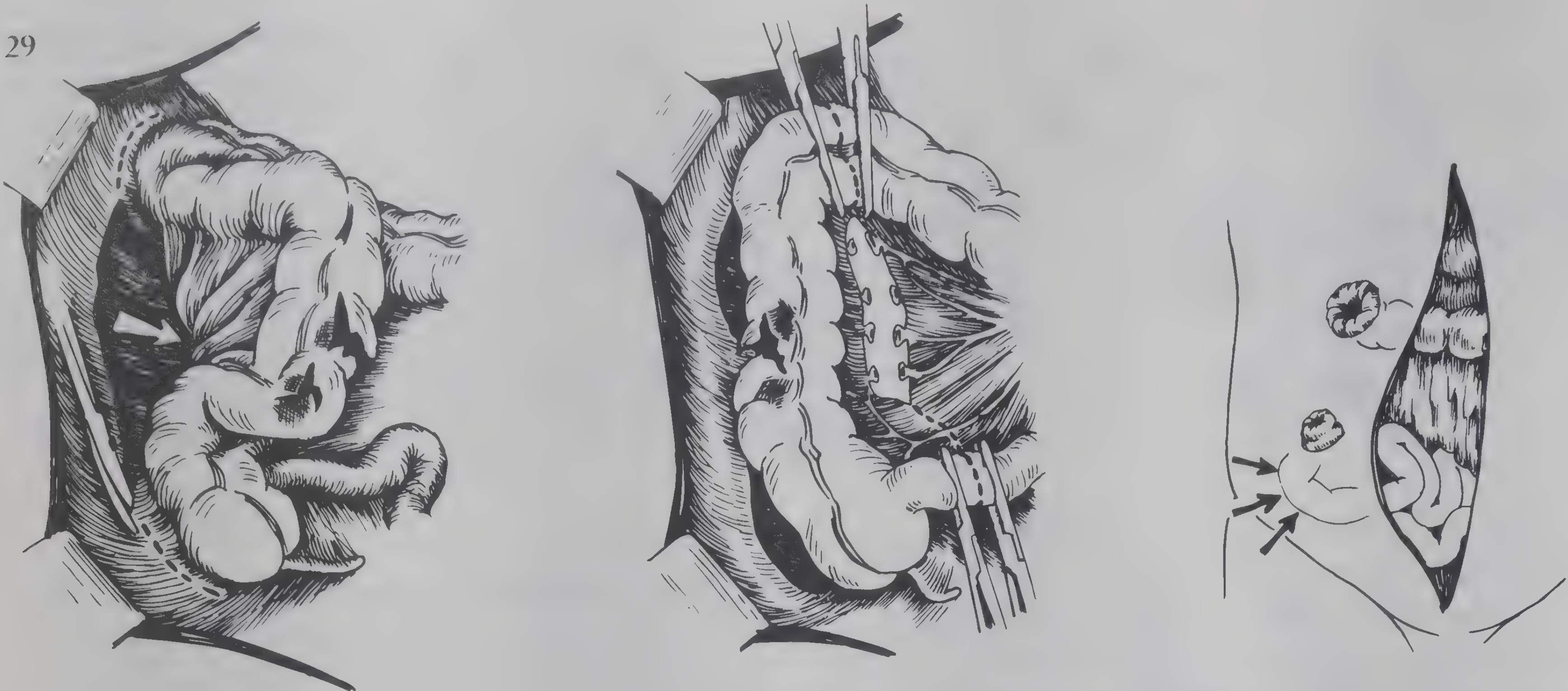


28 The end-colostomy: After resection, the two intestinal ends are delivered without tension through two small separate incisions in the abdominal wall. The colostomy incisions should be located well away from the pelvic bone, from the midline incision and any other skin wounds. The intestine is fixed by some sutures from the serosa to the deep abdominal fascia. Without these sutures, loops of the small intestine may herniate along the colostomy into the abdominal wall. The mucosa is sutured with close interrupted sutures to the skin.

The particular problems of the right colon

The standard procedure for wound suture and diversion enterostomy does not work well for right colon injuries: Enterostomy of the right colon normally creates skin problems, abdominal wall infection and abdominal abscess formation at the site of the stoma.

29

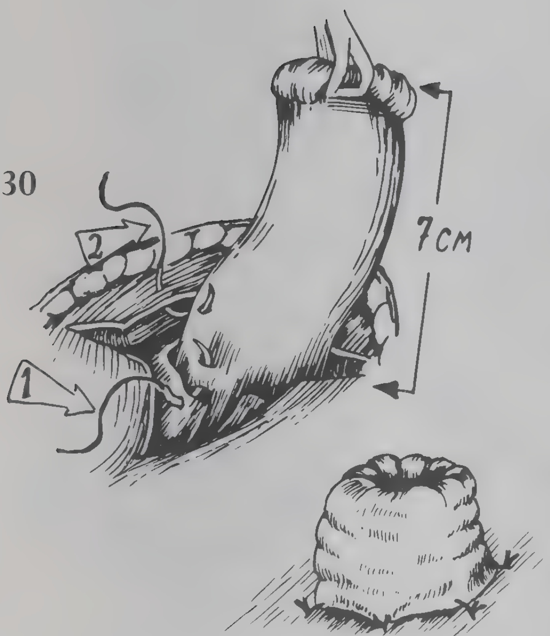


29 The standard procedure – resection of right colon: The experienced doctor should manage major injuries to the right colon with resection of the right colon (right hemicolectomy) and enterostomy of the ileum. The simplest alternative is to deliver the resected colon as a mucous end-colostomy as illustrated here.

The resection starts with a long peritoneal incision along the lateral wall. The colon with its arteries is lifted off its bed by blunt dissection. Take care not to damage the ureter (arrow). The right colon with 10 cm of ileum is resected along the dotted line. A left transversostomy and an end-ileostomy is arranged. Close the space (arrows) between the end-ileum and the abdominal wall (ill. 26).

Another alternative is to anastomose the ileum end-to-end to the transverse colon, and make a diversion loop-ileostomy.

30



30 The end-ileostomy: Make a cross-wise incision in the lower right quadrant of abdomen, and excise a circular patch of the skin. Deliver approximately 7 cm of ileum through the incision. Fix the ileum to the abdominal wall with sutures in two layers: from the serosa to the deep fascia (1), and to the superficial fascia (2). Invert the ileum wall, and fix it with interrupted mucosa-skin sutures.

31

31 The alternative procedure – wound suture and Foley catheter enterostomy: The not so experienced doctor should debride and suture the perforation. Supplement an omental tag to protect the suture line. Then mobilize the cecum towards the abdominal wall making a peritoneal incision lateral to cecum. Cut the end of a large-bore Foley urinary catheter and insert it into the cecum through very short stab incisions in the cecum and abdominal wall. Inflate the catheter balloon and close the cecum tightly around the catheter with a purse-string suture. Fix the cecum up to the abdominal wall with some sutures between the cecum serosa and the peritoneum. When the catheter is deflated and removed after two weeks, the fistula will close spontaneously after some days – on the condition there is no abscess formation inside. An alternative to Foley catheter enterostomy is a distal loop-ileostomy.

Primary suture of minor tears
Suturing may be done within four hours after the injury – if there are no major associated injuries, if the patient is stable and has not endured a long period in circulatory shock. Diversion ileostomy is mandatory.

Injury to the rectum

Do not miss the diagnosis: Injuries to the retroperitoneal (pelvic) part of the rectum have few early clinical signs. Blood in the intestine on rectal exploration may be the only indication of a major rectal tear.

Do laparotomy
- to search for associated injuries
- to suture the rectal tear from the abdominal side
- to make a diversion sigmoidostomy

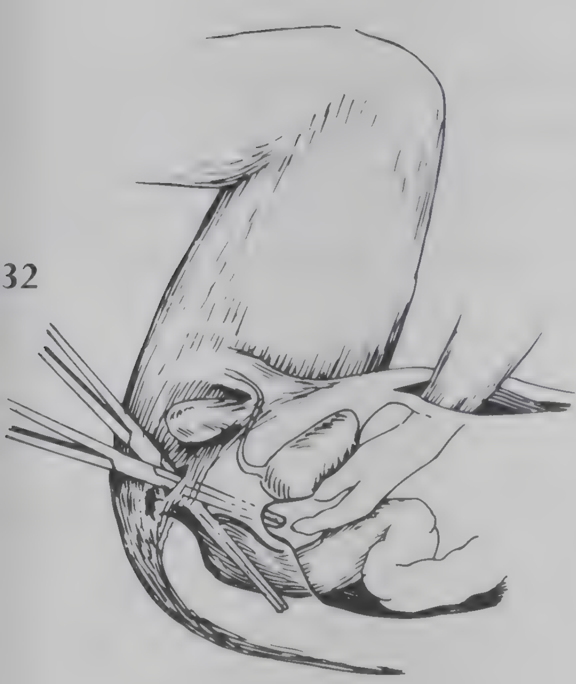
Concentrate on drainage:
- Use of double large-bore drains is minimum
- Consider primary excision of the coccyx bone to improve the drainage
- Dilate anus for better drainage of the rectum

In mine casualties: Alway suspect rectal injury. The perineal inlet wound may be very small.

Injury to the proximal rectum
The injury is closed from the abdominal side. Mobilize the rectum from the pelvis: Incise the peritoneum in the rectovesical pouch, and mobilize the rectum by careful blunt finger dissection (p. 365). The mobilization is bloody, but bleeding is effectively controlled by intermittent gauze tamponade. When the rectal perforation is identified, close it with a two-layer suture without prior debridement. A diversion loop-sigmoidostomy is made.

Injury to the distal rectum
The wound is sutured either from the abdominal side (better), or through the anus after manual dilatation of the anus up to six fingers. One layer of interrupted sutures will do if the external drainage is effective, and a sigmoidostomy is done.

32



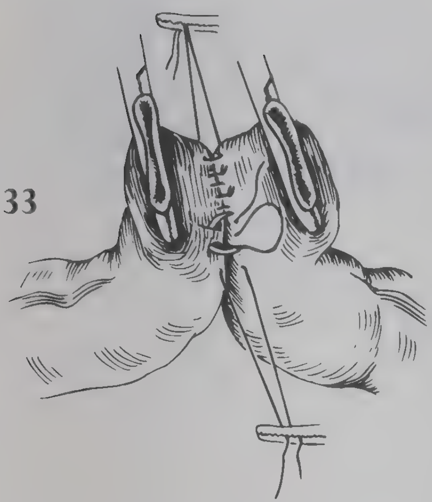
32 **The drainage:** Make an incision in the perineum 2 cm lateral to the anus. Infiltrate some dilute adrenaline solution (anesthetic with adrenaline) deep along the rectum to reduce bleeding. With one hand as guide along the rectum from inside the abdomen – forceps are inserted through the perineal incision along the rectum. Two wide tube drains with side holes are inserted, one anterior to the rectovesical pouch, one posterior along the sacrum bone. In major injuries and cases late for surgery: Excise the coccyx through a perineal midline incision for wide drainage of the pelvic cavity.

Reconstruction after enterostomy

If the intestinal sutures have not ruptured within ten days after surgery, the sutures have healed. The diversion enterostomy can be reversed if the bowel function is normal.

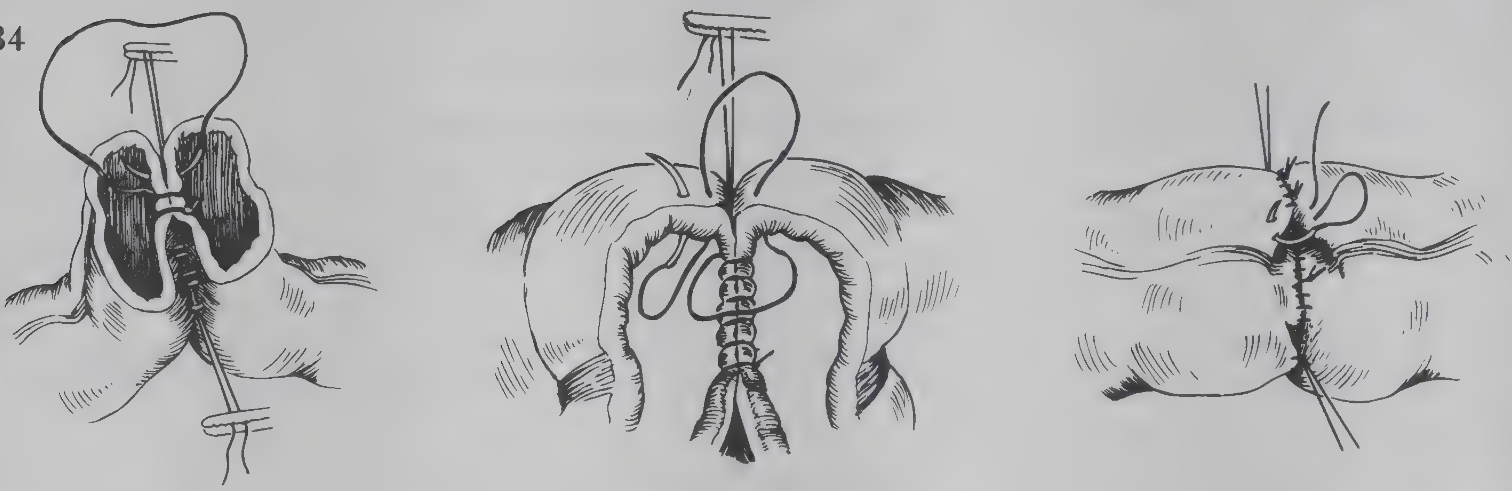
Reconstruction after loop-enterostomy
The intestinal mucosa is released from the skin by sharp dissection. The enterostomy incision is reopened, and the intestine carefully released from the abdominal wall. Pull the loop onto the abdomen; you may extend the incision to get reasonable access. A colostomy is closed with the standard two-layer suture. An ileostomy should not be closed by longitudinal suture: Either close it by transverse suture, or by resection and end-to-end anastomosis to avoid narrowing of the intestine.

33



33 Reconstruction of end-colostomies: First the two barrels of the colostomy are released from the abdominal wall. Clamp the intestinal ends with soft intestinal clamps and mobilize them so that they can be approximated without tension. Extend the colostomy incisions to mobilize the intestines under direct vision. **The posterior outer suture** is done while your assistant is approximating the clamps steadily. The suture is interrupted and includes serosa only.

34



34 The inner suture: The technique is identical with the small intestine anastomosis – a continuous suture (two needles) including all three layers of the wall. Take care to invaginate the edges properly, particularly at the corners. **The anterior outer suture** is interrupted and includes only serosa. Drain the anastomosis: Gastric decompression and external tube drains are arranged before both enterostomy incisions are closed.

Points to note – Chapter 28

Study the anatomy

- note the vessels at the liver hilum: p. 392. Know how to control them by finger clamping: p. 366
- learn how to enter the "lesser sac": p. 363
- note the compartments that should be drained after liver injury: p. 392
- note the risk of associated chest injury: p. 392. Know how to manage combined abdominal-chest injuries: p. 346

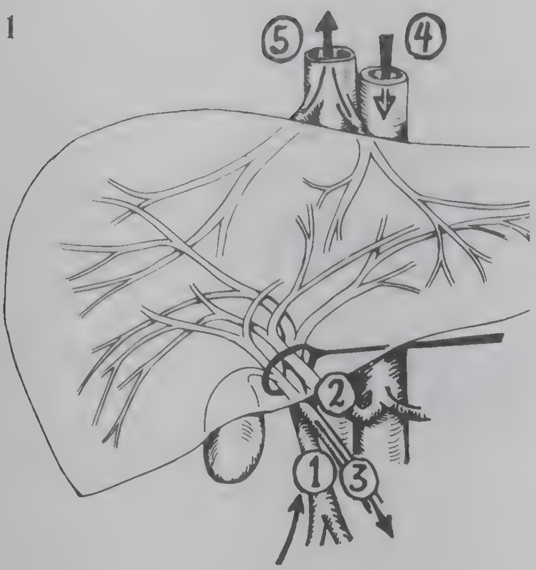
Know how to control bleeding liver injuries: p. 393

Know how to manage gall bladder injuries by suture and decompression: p. 395

28 Injury to the liver and biliary tract

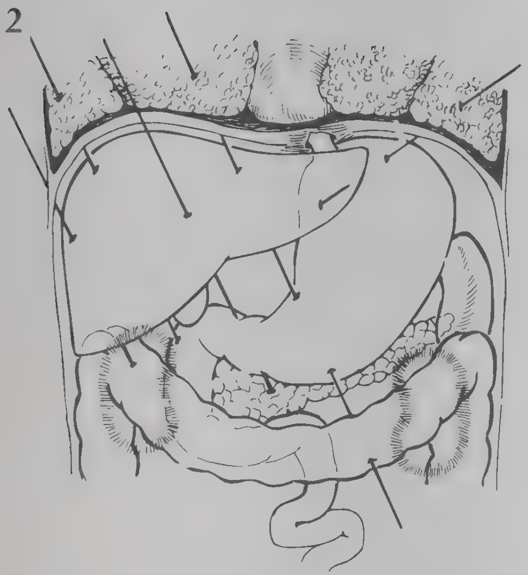
Surgical anatomy

1



1 The blood circulation of the liver: By upwards retraction of the edge of the liver, and downwards retraction of the large intestine, you can identify the liver hilum, the "inlet" to the liver. Note the three structures of the liver hilum (inside the ring): The portal vein (1) carrying nutrition absorbed from the intestines for metabolism inside the liver. The liver artery (2) is a branch of the celiac artery, and carries oxygenated blood from the aorta (4) to the liver tissues. The main biliary duct (3) carrying the bile into the duodenum. The surgeon may temporarily clamp all three structures (Pringle's maneuver) to reduce bleeding from a liver tear. If it still bleeds after hilum clamping, the bleeding source may be the liver veins (5). They are controlled by tamponade of the posterior side of the liver. The liver arteries are not end-arteries. They communicate with the portal circulation. You may thus permanently ligate a liver lobe artery with little risk of liver necrosis if the portal blood supply is undamaged.

2

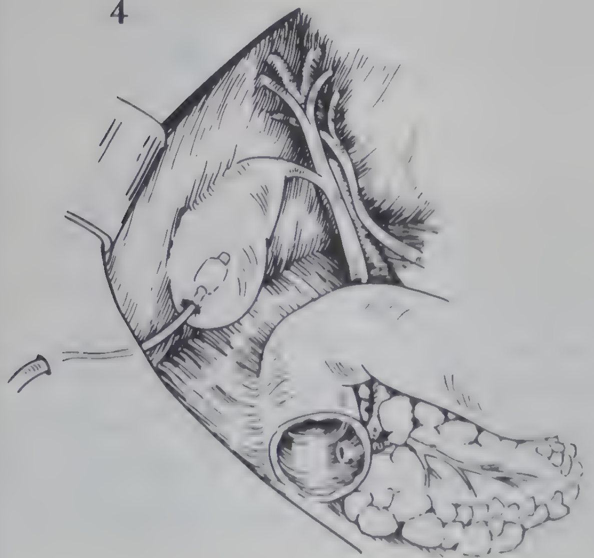


2 Associated injuries are common: In serious cases, when liver bleeding is controlled, do not waste time on further liver surgery. Concentrate instead on exploration of the duodenum, pancreas and colon as these injuries cause peritonitis and infect the liver tears. **Note** the position of the left lobe of the liver: It is often injured by missiles penetrating the midline from the left side. Combined injuries of the right kidney and the right lobe of the liver are common as they are located at the same level.

3

3 Abscess formation after liver injury: Hematomas not drained may form abscesses. The arrows show where blood and bile normally collect. Note especially the pocket behind the stomach and the gastro-colic ligament and downwards to the transverse colon (the lesser sac). And the space between the ribs and the right lobe (black arrow). Two or more large-bore dependent drains through the lateral abdominal wall (right or left side) will prevent abscess formation. The liver is lined by a capsule, and hematomas may also form under the capsule if liver tears are tightly sutured.

4



4 The biliary tract: The bile ducts from the liver, the gall bladder and the main bile duct together form the biliary tract. When the free flow of bile down to the duodenum is impaired, jaundice arises. Biliary tract decompression after injury is done either by drain into the gall bladder or by T-drain from the main bile duct. Note that as the distal part of the main bile duct is covered by peritoneum, you have to incise it to explore the duct (p. 363). The duct runs behind the duodenum, through the head of pancreas before it enters the duodenum. To explore the distal part of the bile duct, you must therefore mobilize the duodenum (p. 364). The gall bladder may rupture by the spalling effect of blast waves (p. 83). Minor tears of the gall bladder are more common. They heal well after moderate debridement, suture and effective bile drainage. As missile injuries of the main bile duct are normally associated with major vascular injury, most patients die before surgery.

Liver injury

Also see: Basic life-saving surgery, p. 155.

Autotransfusion: Collect blood for autotransfusion if there is no associated intestinal injury. The platelets are more important than surgery to control major liver bleeding. See p. 270.

The essentials of the management: Be conservative!

- **Wide wound tracks:** Like muscle tissue, the tissue of the liver is not elastic. High-energy injuries (penetrating and blunt) may cause wide wound tracks. The missile shock wave may form hematomas and abscesses at some distance from the wound track. Explore the liver well.
- **Spontaneous healing:** The liver tissue is very well vascularized. Even major tears heal without debridement. Effective drainage is essential.
- **Control bleeding – step one:** In minor and moderate liver tears the bleeding would normally have stopped spontaneously at the time of surgery. In major injuries, first reduce bleeding by Pringle's maneuver (p. 366).
- **Control bleeding – step two:** Then pack the liver tear with loose gauze swabs. Under mild compression even major bleeding is controlled. Leave the tampon for 24-48 hours.
- **Control bleeding – step three:** At a secondary laparotomy the gauze packs are carefully removed, and drainage arranged.

Concentrate on the associated injuries – not on primary liver surgery: Heroic primary liver surgery with extensive debridements, resections and lobectomies increase the mortality rate even in experienced hands. When the liver bleeding is under control, concentrate on injuries of the intestine and pancreas to prevent secondary infection of the wounds and hematomas of the liver. Infection causes rebleeding.

The incision: A long midline incision with retraction of transverse colon downwards and the ribs and diaphragm upwards gives good access to the liver. Sternum split or extensive thoraco-abdominal incisions are seldom necessary.

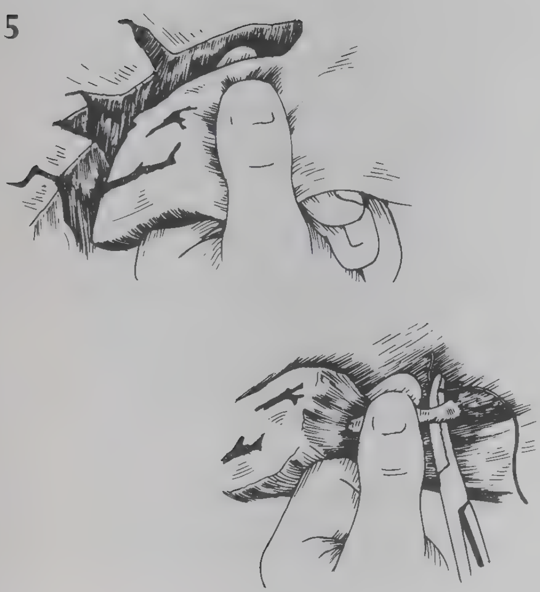
For better access, the falciform ligament at the top of the liver may be cut.

Injuries to the liver veins and the posterior side of the liver should be managed with packing and drainage only, which is well done through the midline incision.

The bleeding has stopped: Normally bleeding from minor and moderate tears would have stopped spontaneously at the time of surgery. If the tear is a major one, carefully make a tampon of loose gauze and leave the tear without further manipulation. Debridement and suture may cause heavy rebleeding. The patient should be closely monitored in bed for 48-72 hours before the second-look laparotomy is done. If monitoring and secondary surgery are not possible due to evacuation, the tampon may be removed blindly. A moderate or minor tear may be sutured at the time of primary surgery if the patient is in a stable condition.

The control of bleeding: Hilum compression (Pringle's maneuver) may be done by direct "finger clamping". Better still is to split the peritoneum and clamp the structures of the liver hilum all-in-one with a vascular clamp (p. 366). You may maintain the clamping continuously for 30 minutes, and even up to 60 minutes in emergencies. Fresh whole blood is important to control liver bleeding in hypovolemic and hemodiluted cases; blood transfusion should start once the bleeding is under control. **Note:** Venous bleeding from a liver tear may be heavy and continue for minutes after the hilum clamping is done.

5



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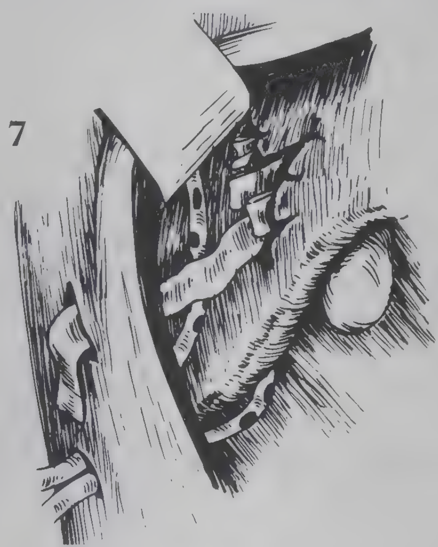


5 Debridement of liver tissue may be done in stable cases and during the second-look laparotomy if the tear is superficial. Only the obviously necrotic liver tissue is "cut", pinching it between the fingers. You will feel the major bile canals and vessels between your fingers. Clamp them with forceps, and tie them with ligature. To prevent rebleeding: Do not debride deep into the liver, better concentrate on drainage. Do not make major debridements without blood transfusion facilities.

6 The liver suture: Moderate bleeding from superficial tears may be controlled by deep hemostatic sutures with big curved non-cutting (round) needle. Do not tie the sutures tightly, as they may tear the liver tissue, cause necrosis, and retention of blood and bile with abscess formation. You may insert hemostatic gauze, a part of omentum or crushed muscle ("postage stamp" – p. 367) into the wound before you apply the hemostatic suture.

7 Temporary tamponade is applied if military problems make two-step surgery impossible. A long ribbon gauze is packed loosely into the liver wound and delivered through a separate stab incision in the abdominal wall. The tampon is removed stepwise after 48-72 hours while you closely monitor the drains for rebleeding.

The drainage

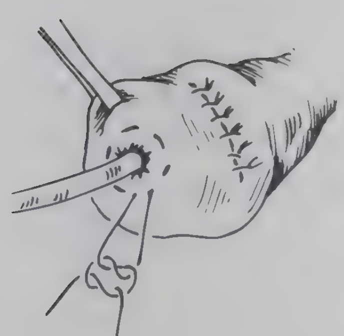
Drain the spaces where hematomas normally collect (ill. 3) with large-bore tube drains with side holes. Also apply drains close to, but not into, the liver tears. To achieve effective dependent drainage, the drains are inserted far lateral through the abdominal wall in the anterior axillary line. Register in the Patient Chart or with marker on the skin which tube drains which space. Monitor the drains closely for signs of rebleeding when you restore the blood volume. And for signs of infection 4-6 days after the injury.

Complications of liver injury and surgery

- **Rebleeding** may occur 4-8 days after the injury. The reason may be infection (see below). Or coagulation system failure: After major liver injuries, disorders of the liver metabolism may cause a general bleeding tendency. Not only the liver wounds start to bleed, but spontaneous bleeding also arises in the stomach and intestines. The mortality rate is high. The best management is preventive: early transfusions of cross-matched fresh whole blood, and high-energy nutrition.
- **Abscess formation** is caused by poor drainage and/or missed diagnosis of liver wounds. The signs are a worsening general condition, "abscess fever" with intermittent peaks of the temperature – and sometimes a dull pain that may be referred to the right shoulder. X-ray examination is of little value in the diagnosis of intra-abdominal abscess formation. The management is urgent exploration and drainage. Search all compartments where abscesses may form (ill. 3). There is often more than one abscess. Wash out the abscess and apply effective drainage. Antibiotics are of less value.
- **Leaking of bile:** Some leaking of bile through the drains should be considered normal – just monitor and wait. Neither should moderate local irritation of the peritoneum of right upper abdomen due to free bile cause alarm. Increasing signs of bile peritonitis or bile loss through the drain should be acted upon: Reoperate and arrange decompression of the biliary tract (ill. 4). A bile fistula along the drain or through the midline incision will normally close spontaneously within months.

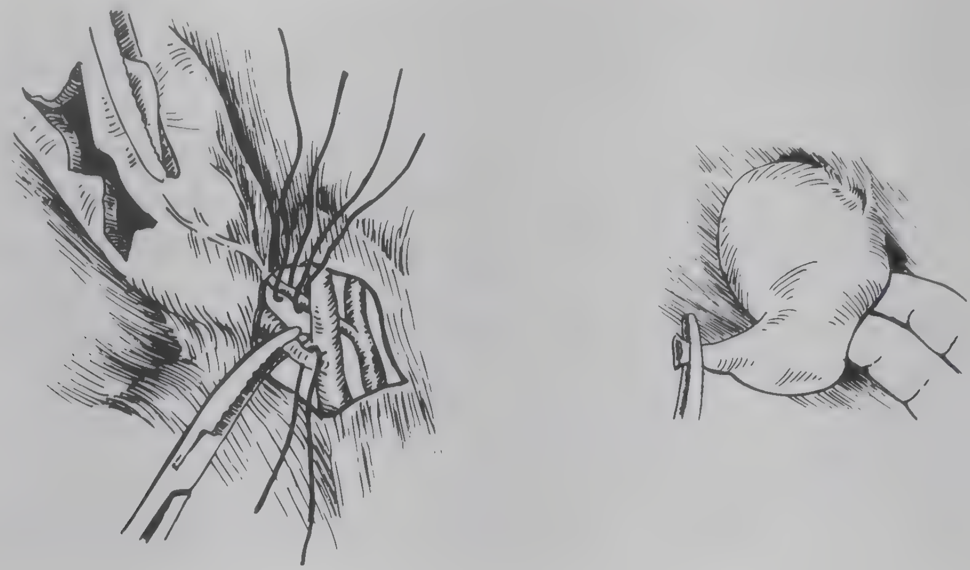
Injury to the biliary tract

8



8 Minor gall bladder injury – suture and decompression: Debride wounds of the gall bladder before suture. Insert a small-caliber Foley catheter through the abdominal wall and into the bladder through a small stab incision in the bladder wall. Supplement with dependent tube drainage of the liver hilum. Leave the gall bladder drain for 10 days. When you remove it, a bile fistula probably develops which normally closes spontaneously after some time.

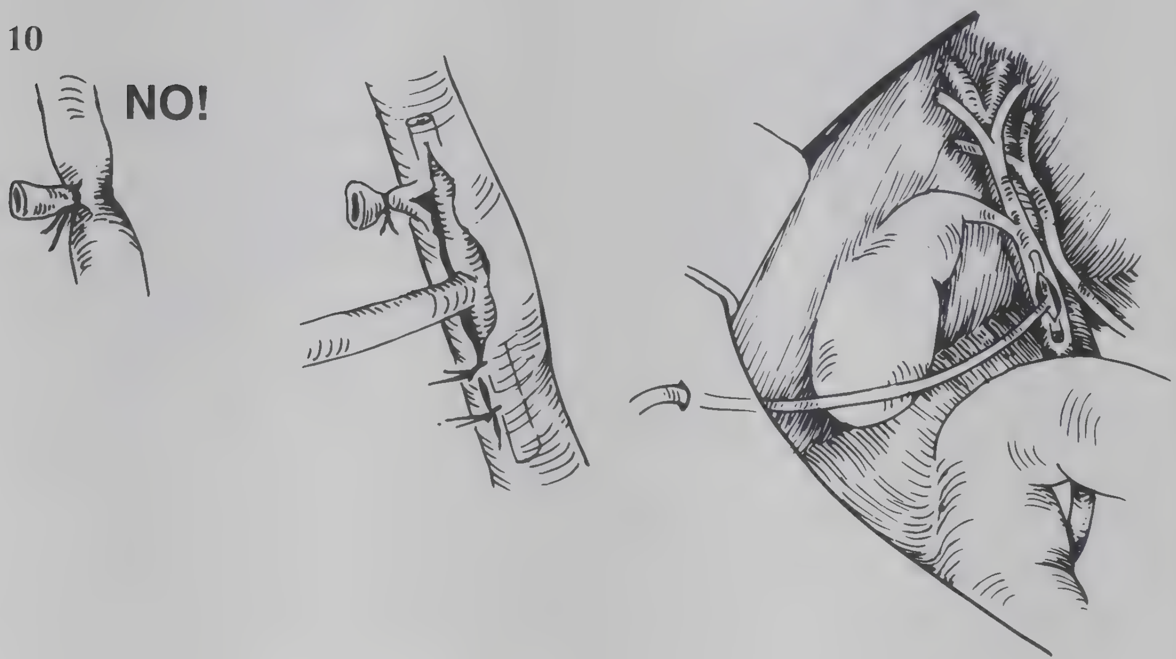
9



9 Major gall bladder injury – do cholecystectomy if you feel competent: Split the peritoneum at the hilum, and identify the liver artery and the main bile duct by careful blunt dissection. First tie the gall bladder artery (two ligatures), then the gall bladder duct. **Note:** The anatomy of this area is not constant – the gall bladder artery may be single or double, it may leave the hepatic artery at different levels. Despite the small caliber of the artery, it may bleed considerably and be difficult to control if once lost. Then free the bladder from its attachment to the liver by blunt dissection. Keep a steady pull upon the bladder during the dissection. Dependent drainage.

The rapid alternative: Resect the bladder distal to the tear and close the remaining part of the bladder around a small-caliber tube drain. You may use a tag of omentum to supplement the bladder suture (p. 403).

10



10 Injury to the main bile duct: During cholecystectomy, take care not to tie the main bile duct. A careless ligature of the gall bladder duct may cause stricture upon the main duct, and jaundice. The management is drainage by T-tube or a plain soft plastic tube for two weeks. Missile tears and total ruptures of the main duct are also managed by primary bile duct drainage, and secondary reconstructive surgery.

Points to note – Chapter 29

Study the anatomy
- note the blood vessels of the stomach: p. 401. And how to explore the posterior side of the stomach: p. 363
- note the blood vessels of the duodenum: p. 401. And how to explore the posterior side of the duodenum: p. 364

Close stomach wounds
- note the suture technique: p. 401
- learn to do Foley catheter gastrostomy: p. 369

Duodenal injuries are often missed
- there are diagnostic problems in duodenal injuries: p. 400 and 402
- know how to manage duodenal injuries by drainage: p. 403
- do not enter a retroperitoneal hematoma: p. 405

29 Injury to the stomach and duodenum

Surgical anatomy

The structure of the stomach and duodenum is identical to that of the intestine: The wall consists of three layers – mucosa, the muscular layer and serosa (p. 376).

Stomach missile injuries
Both diagnosis and surgery are simple: Blood with gastric suction indicates surgical exploration. As the blood supply to the stomach is abundant, tears heal well after moderate debridement and suture. The main problem is retention of duodenal and gastric acid content in the stomach after surgery which may cause rupture of the sutured wound. Gastric decompression with intermittent suction via naso-gastric tube is important.

Duodenal missile injuries
In nine out of ten cases with duodenal injury there are associated injuries, often to major vessels. Most high-energy injuries die before they reach surgery.

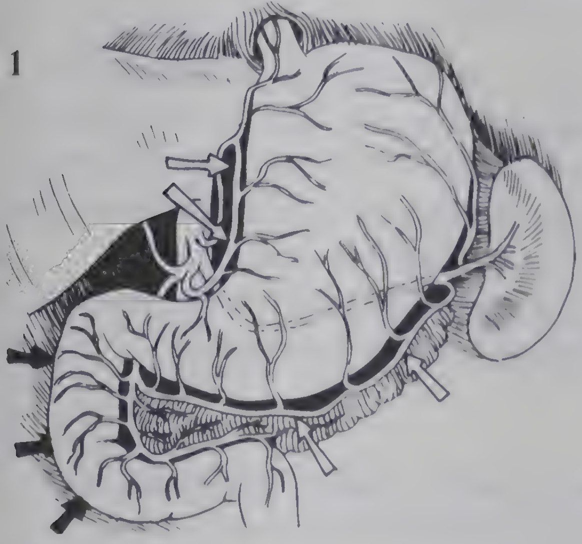
- Diagnostic problem – 1: Blunt injuries and missile injuries with posterior inlet may cause tears of the posterior wall, that is, retroperitoneal perforations of the duodenum. There is no leaking into the peritoneal cavity and the early clinical signs may be few.
- Diagnostic problem – 2: Blunt injury and heavy blast waves may cause hematomas in the duodenal wall with swelling and partial/total obstruction of the duodenum, a condition seldom seen elsewhere in the gastro-intestinal tract. Except for gastric retention of fluid, the early clinical signs may be few. A missed and unmanaged hematoma of the wall may rupture within a few days.
- Surgical problem – 1: The total physiological secretions passing into the duodenum – from the stomach, pancreas and the biliary duct – amount to 4-5 liters per 24 hours. This causes pressure upon the suture line, and high risk of rupture of the suture line with peritonitis and fistula formation. Proximal as well as distal drainage is mandatory. Enteral feeding should be considered due to the prolonged recovery.
- Surgical problem – 2: As the lumen of duodenum is narrow, suture of even small tears may cause partial or total obstruction of the intestine.

High injuries of the small intestine (proximal jejunal injuries)
These injuries are discussed in this context. The surgical problems with these injuries are nearly identical to those of the duodenum, and the same management procedures should be applied.

Blunt and blast wave injuries
Such waves may damage both the stomach and duodenum. In high-energy injuries, both the duodenum and stomach may rupture in a blow-out fashion with wide tears of the wall. Hematomas of the wall may cause duodenal obstruction. The proximal jejunum contains less gas, is more mobile, and less prone to blunt injuries.

The spalling effect: p. 82.
Blast wave abdominal injury: p. 83.

1



1 The vascular supply: There is a rich anastomosing network between the main arteries along the greater and lesser curvature of the stomach (white arrows). As these arteries are not end-arteries, you may ligate them without risk of stomach wall necrosis. Note the artery for duodenum along the inner curvature of duodenum. Along the outer curvature there are few vessels – the duodenum and the head of pancreas are therefore mobilized (Kocher's maneuver – p. 364) by bloodless dissection from the outer curvature (black arrows). Always explore the pancreas in injuries to the stomach, duodenum and spleen: The pancreas has no separate independent blood supply; it is supplied from the gastric, duodenal and splenic circulation. Injuries to these organs may cause partial necrosis of the pancreas as well.

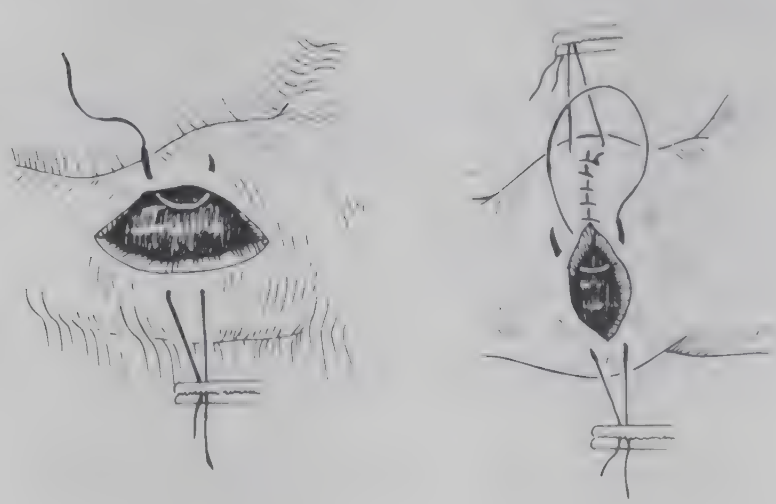
2

2 Anatomy of the duodenum: In this illustration the gastro-colic ligamentum (p. 362) is not drawn. Note that the main portion of duodenum lies behind the peritoneum, directly fixed to the posterior abdominal wall without any mesentery. Below the ligament of Treitz (white arrow) the jejunum starts, with loops lying free inside the abdomen connected to the posterior abdominal wall by the mesentery. Consequently, most perforations of the duodenum do not cause the typical acute peritonitis seen after more distal intestinal injuries. If you recognize a duodenal injury by its peritonitis, you are probably too late and will face difficulties during surgery. Note the superior mesenteric artery (big black arrow) carrying the main blood supply for the small and large intestine. The artery runs through the body of pancreas, and crosses the duodenum at its distal third. The small black arrows indicate the area with few blood vessels that should be divided for exploration of the posterior wall of the duodenum (p. 363).

Stomach injury

Look for the other perforation: Isolated wounds of the stomach are uncommon in missile injuries. Split the gastro-colic ligamentum and explore the posterior wall.

3



3 Closing stomach perforations: The perforation is roughly debrided and stay sutures applied. In the distal part of the stomach, longitudinal wounds should be transformed into transverse ones to prevent narrowing. The wound is closed with two layers of sutures as described for tears of the colon. The inner continuous over-and-over suture is applied with a close interval between each suture to control mucosal bleeding. The outer suture is interrupted, contains just the serosal layer and must invaginate

the inner suture. A strand of omentum may be used to protect the suture line (ill. 5). Before you close the stomach wound, guide a tube into the duodenum for decompression. Start suction on the operating table and continue intermittent suction for 3-5 days. Arrange dependent drainage of the space between the stomach and transverse colon, and of the lesser sac if the wound is on the posterior wall. Even wide tears of the stomach are managed by direct primary suture. Major resections and gastro-jejunostomy are rarely indicated.

Enteral feeding
In more than minor stomach wounds, give enteral feeding by a duodenal tube for one week after surgery to avoid pressure upon the suture line (p. 614).

Injury to the duodenum and proximal jejunum

Laparotomy within eight hours
Explore the duodenum on the slightest suspicion of perforation, and within eight hours after the time of injury. Beyond this limit, surgery is complicated by local swelling and difficult dissection. The risk of fistula formation and secondary peritonitis increases.

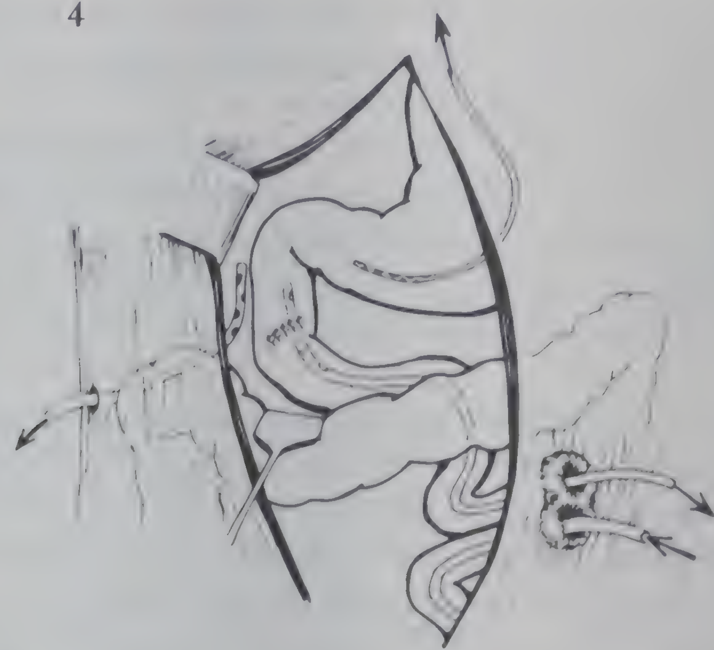
The early clinical signs of injury may be few, indicators may be
- Pain in the central abdomen
- Referred back pain
- Tenderness and swelling of the lateral abdominal wall
- Constant vomiting and poor general condition

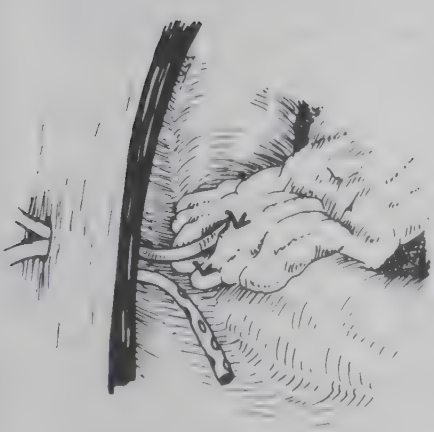
Indicators of duodenal injury during surgery:
- Retroperitoneal hematoma and/or swelling
- Retroperitoneal gas
- Discoloration due to bile leaking

Prepare for vascular emergencies: Associated injury to main vessels is common. If you have to open retroperitoneal hematomas to manage the duodenum, expect grave bleeding.
- Blood-type before surgery
- Double i.v. lines running
- Vascular clamps at hand
- Be ready for aortic compression or clamping

Emergency laparotomy, aortic compression: p. 365.

4





4 The optimal management – suture, decompression, drain and enteral feeding: The debridement should be limited, only rags are excised from the wound edges. Close the wound with a two-layer suture: The inner continuous over-and-over suture, the outer interrupted serosa suture should invaginate the wound well. A tag of the omentum may be fixed to the suture line with some interrupted serosal sutures (p. 381). Deliver a proximal loop of jejunum through a separate left lateral incision, and arrange a loop-jejunostomy (p. 382). Before you close the midline incision, pass a soft tube guided with your hand through the jejunostomy into the duodenum for decompression. Pass the distal tube through the jejunostomy into the small gut for enteral feeding. A naso-gastric tube is applied for decompression of the stomach for 5-10 days. At least one large-bore tube with side holes should drain the area close to the duodenal suture. By this tube drain you can monitor the patency of the suture. Also the tube will make the track for the duodenal fistula that develops in case of wound rupture. Take the tube out through a far lateral separate stab incision.

5 The emergency alternative – a controlled duodenal fistula: In multi-organ injuries, during emergency laparotomies and in cases late for surgery, it may be a hazard to do extensive primary duodenal surgery. Also if you are inexperienced in abdominal surgery, the controlled fistula is a safe alternative: Make two side holes in a wide-bore Foley catheter and insert it through a separate far lateral stab incision in the abdominal wall and into the duodenal perforation. Inflate the balloon slightly. Adapt the wound edges around the catheter as best you can, and fix a strand of the omentum to the area with some interrupted sutures. Proximal and distal decompression (ill. 4) is essential. High-energy enteral feeding through a loop-jejunostomy is a must as the rehabilitation will be protracted. Two weeks after surgery the duodenal balloon is deflated and the catheter withdrawn stepwise, some cm every day. Probably a duodenal fistula will form.

Blunt injury without perforation: Explore the retroperitoneal duodenum to be sure there is no perforation. Also explore the pancreas: Leaking of pancreatic juice may cause perforation in a hematoma in the duodenal wall. The management of the duodenal injury is conservative: Concentrate on proximal

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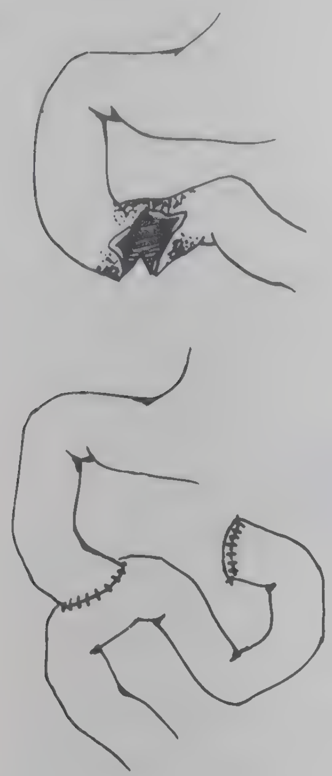

decompression with intermittent gastric suction for 5-10 days. The management of retroperitoneal hematoma: p. 405.

6 Extensive duodenal injury: In cases with loss of tissue and extensive tears, suture will invariably cause obstruction of the relatively small lumen of the duodenum. Duodeno-jejunostomy is indicated: Close the duodenum distal to the tear with a two-layer suture. Anastomose the proximal part end-to-side on a proximal loop of the jejunum.

Injury to the proximal part of jejunum

The perforation is debrided and closed – minor perforations with plain suture, major or multiple perforations with resection-anastomosis (p. 378). Then the jejunal loop distal to the perforation is delivered through a separate incision as loop-jejunostomy (ill. 4). Two soft catheters are inserted – one into the duodenum for decompression, the other into the small gut for enteral feeding. Supplement with intermittent gastric suction for some days.

Emergency procedures

Secondary organ failure: p. 388.

Re-establish the intestinal blood flow as soon as possible

Not only may the patient die from bleeding, also the risk of serious complications increases with lengthy hypoxemia of the abdominal organs:

- The intestinal necrosis is extended
- The risk of rupture of intestinal sutures is increased, particularly so in the duodenum and upper jejunum
- The risk of secondary organ failure (ARDS) is proportional to the duration of organ hypoxemia

The emergency laparotomy in detail: p. 155.

Emergency laparotomy is done on patients in grave shock that do not respond to intensive volume therapy. Such surgery is considered part of the basic life support procedures – the main objective is to control bleeding and start transfusions to re-establish the blood flow in vital and abdominal organs. The management of injured organs themselves has second priority, only simplified procedures are done during the emergency laparotomy. The duration of the laparotomy should not exceed one hour. If the patient survives the bleeding, a second laparotomy is done within 24-72 hours. Then organ repair is done according to the guidelines discussed above.

Control bleeding

The stomach wounds seldom bleed much. But vascular damage in the area of the duodenum is common.

- Major intraperitoneal bleeding: If thoracic clamping of the aorta is not done before the laparotomy, compress the aorta as close to the diaphragm as possible. Also compress the aorta against the lumbar spine distal to the injury

to reduce the back-flow. Remove the blood – identify the bleeding site and examine the duodenum, pancreas, right kidney and the liver hilum.

- Retroperitoneal bleeding: Do not enter a retroperitoneal hematoma unless it is obviously expanding. Most retroperitoneal hematomas are managed by packing without further surgery. Avoid manipulation of the hematoma during the organ exploration – better delay the routine exploration until the second-look laparotomy when the platelet count and hemoglobin level should be normalized. If you have to split the peritoneum, first apply proximal and distal clamps on the aorta.
- Packing, ligature or reconstruction? Suture tears of the aorta, the superior mesenteric artery and the caval vein. Other vascular injuries are managed with ligature if they cannot be safely controlled by gauze packing: ligature of the splenic artery and primary splenectomy. Ligature of the hepatic artery is safe if the portal vein is not damaged. Ligature of one renal artery indicates nephrectomy, a time-consuming operation that should be delayed until the second laparotomy.

Abdominal vascular injury: p. 367.

Exclude chest injury

Effective respiration is more important than abdominal organ repair. Examine the diaphragm carefully – minor tears may cause hemothorax formation. Close diaphragmatic wounds by one-layer continuous suture.

Drain the duodenum

- You may leave the duodenal injury unmanaged: Concentrate on naso-gastric suction.
- Intraperitoneal duodenal injury: Before the upper abdomen is packed with gauze, you may insert a tube drain through the duodenal tear into the intestine (ill. 5).
- Retroperitoneal duodenal injury: Do not mobilize the duodenum during on-going bleeding – it is time consuming and will increase the bleeding. Consider inserting a drain through the anterior duodenal wall, but note that you may thereby indirectly be entering the hematoma and spoiling the possibility of effective gauze packing.

Complications of injury and surgery

Complications of stomach surgery

They are not common. There may be slight bleeding by the naso-gastric tube the first day after operation. If the bleeding continues, reoperation should be done with adequate hemostatic sutures of the wound. Probably a small gastric artery in the wound edge is bleeding. The main reason for complications is missed wounds of the posterior wall of the stomach.

Paralytic ileus after duodenal surgery

Compared to other intestinal injury, the gastro-intestinal function resumes late after surgery on the duodenum and the proximal part of the jejunum. Too early

peroral feeding may cause retention, vomiting and increased risk of intestinal wound rupture. In some cases the paralytic state may last for weeks after surgery:
• Continue gastric decompression.
• Establish jejunal feeding if that was not done at the time of primary surgery.

Rupture of the suture line and peritonitis
There is no wait-and-see: reoperate on suspicion. Wash with abundant saline and insert Foley catheter for drainage through the ruptured wound. Drain the area well. Extensive surgery, resections and reconstructive procedures should be delayed until the peritonitis is managed. High-energy enteral feeding is mandatory.

Duodenal fistula
The fistula normally closes spontaneously. Note that there is a great loss of fluid, salts and essential minerals by the fistula. Unless compensated by jejunal feeding, an extreme catabolism will develop carrying a high mortality risk due to secondary complications. In a catabolic and weak patient the fistula will probably not close spontaneously – reconstructive surgery is indicated, at best before the catabolism becomes too advanced.

Nutritional failure: p. 610.

Duodenal stenosis
The patient recovers, but complains of constant vomiting: Suspect narrowing of the injured part of the duodenum. If X-ray facilities are available, examine the degree of obstruction after peroral barium contrast. Continue gastric suction and enteral feeding. Most cases of partial stenosis recover without reconstructive surgery. Complete obstructions 10 days after the surgery will normally not recover: Reconstruction is indicated (gastro-jejunostomy or duodeno-jejunostomy – ill. 6).

Points to note – Chapter 30

There are often associated chest injuries

- study the anatomy: p. 340 and 410. Do not damage the spleen when you insert chest tubes: p. 142

The only safe management of splenic injuries is immediate removal of the spleen. But do not start on splenectomy unless you are guided by experienced staff, or have trained on animals or cadavers.

Emergency measures:

- learn how to identify and control the splenic artery and vein: p. 411
- as a temporary measure, you may control most splenic injuries by gauze packing: p. 365. But note the risk of rebleeding: p. 412

30 Injury to the spleen

Surgical anatomy

The spleen consists of loose connective tissue covered by a thin capsule. Low-energy missiles, blunt injuries and blast wave injuries may all cause considerable tears of the spleen. High-energy injuries cause total rupture of the organ.

Splenic injury

- Bleeding: The blood circulation through the spleen is considerable, even minor splenic injuries may cause massive bleeding.
- Associated injuries: Isolated missile injuries of the spleen are uncommon. Always look for injury to the lung, stomach, colon, pancreas and right kidney.

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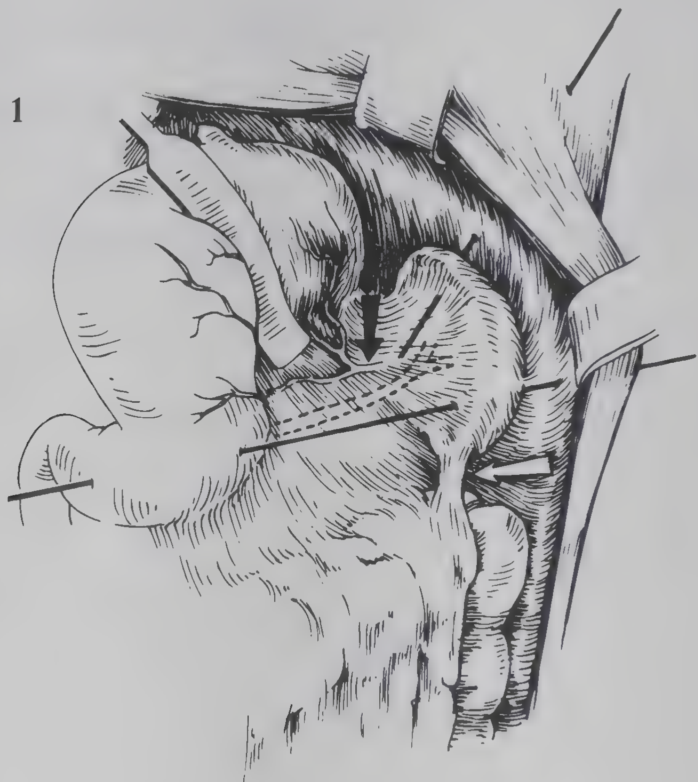
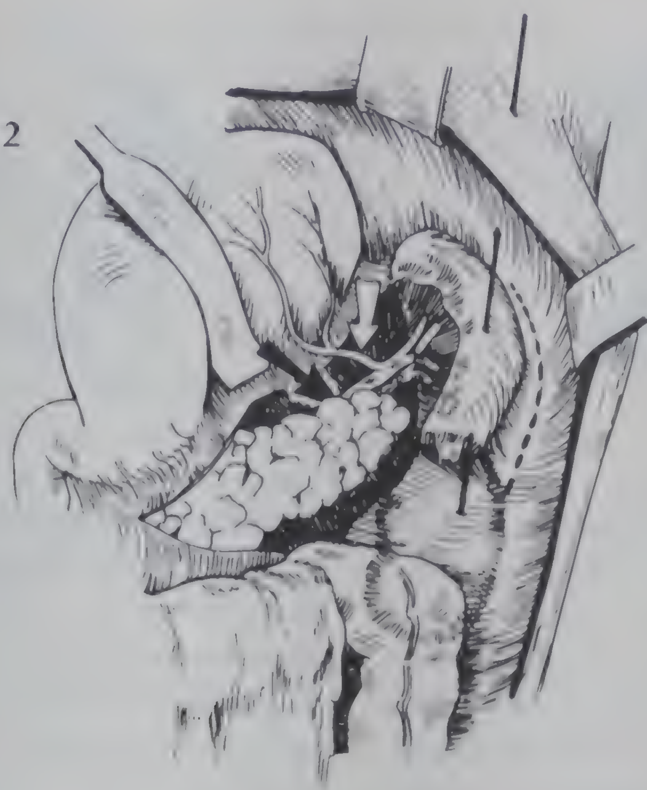


1 Relationship to other organs: The spleen is located behind the stomach. To expose it, the stomach with omentum is retracted to the right, and the transverse colon downwards. Note the close relation to the diaphragm and the left lung. The splenic artery and vein (dotted) are located inside the broad peritoneal sheet ("the small omentum", the gastro-colic ligament) between the stomach and the transverse colon. The black arrow points to some branches of the splenic artery supplying the stomach (short gastric arteries). These arteries may be damaged during careless exploration of the spleen; they are a common source of bleeding in upper abdominal injury. From the lower part of the spleen down to the transverse colon runs a strand of omentum (white arrow). It contains some vessels and may also bleed if torn.

2

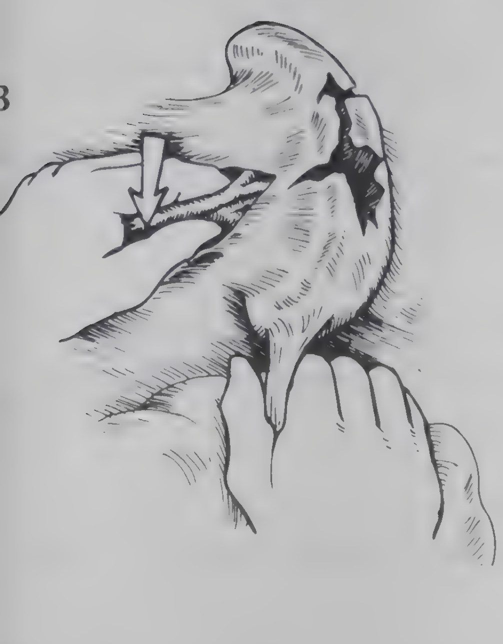


2 The splenic artery and vein (black arrow) are exposed by blunt dissection after splitting the peritoneal ligament between the stomach and the spleen. The two vessels run together at the upper border of pancreas and slightly behind the pancreas. In order to "finger clamp" the splenic vessels to control bleeding, the surgeon must thrust his fingers posterior to the tail of the pancreas. Observe that the pancreas may be torn during this maneuver. The dotted line illustrates the lateral peritoneal incision used to mobilize the spleen for exploration or splenectomy.

Removal of the spleen – splenectomy

In general, there is no wait-and-see, and no other management of wartime splenic injury except removal of the spleen. You may find missile injuries where the splenic bleeding has stopped spontaneously at the time of exploration – the only sign of injury may be a hematoma under the splenic capsule, or along the splenic vessels. Without splenectomy rebleeding may occur after 1-4 weeks, often with fatal result. Thus conservative management has no place in forward wartime surgery. In infants and small children you may carefully suture minor tears of the spleen (non-cutting needle) as their splenic capsule is thicker.

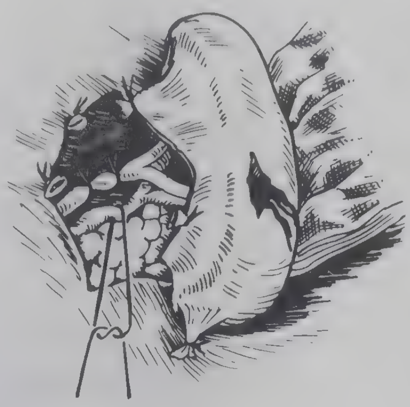
3



3 Procedure: The midline incision gives good access to the spleen. Retract the stomach with omentum to the right and the transverse colon downwards. Blood is removed from the space under the spleen and along the left colon. If the spleen bleeds heavily, go for the splenic artery at once! Split the peritoneum between the stomach and the spleen, and finger clamp the splenic vessels for some minutes while transfusions/infusions are flushed. Let your assistant maintain the finger clamping, while you mobilize the spleen to identify the anatomy and the injury exactly.

4

5



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4 Mobilize the spleen: In cases with heavy abdominal bleeding, you may ligate the splenic vessels before you mobilize and remove the spleen. If the bleeding is moderate, the spleen is first mobilized from the abdominal wall by incision of lateral peritoneum (the dotted line, ill. 2). By blunt finger dissection it is gradually lifted forwards into the midline incision. Pack the space between the spleen and the lateral abdominal wall with gauze packs to control oozing of blood before you continue the operation.

5 Control the splenic vessels: The spleen is gently lifted forwards from its bed by gauze packing. Split the peritoneum between the stomach and the spleen, and isolate the splenic artery and the splenic vein by careful blunt dissection. First the artery and then the vein is ligated doubly and cut. Note the ligature upon the cut strand of omentum from the lower pole of the spleen.

6 Avoid pancreatic tears: The spleen is carefully lifted from its bed. Adhesions to pancreas are carefully wiped off. Careless dissection may tear the tail of the pancreas (arrow). Pancreatic tears leak pancreatic juice which may cause serious complications (p. 416). Bleeding in the splenic bed is controlled by 10 minutes' compression upon gauze packs. Large-bore dependent tube drains are inserted through a stab incision in the anterior axillary line.

Complications of injury and surgery

Lung complications

- Early: Left-sided hemothorax may develop during 24 hours after the injury. The reason is probably suction of blood from the splenic bed through a minor diaphragmatic injury. Even if the chest was cleared before surgery, re-examine for signs of hemothorax after surgery.
- Early: Atelectasis of the left lung is common unless early active respiratory exercises are done under analgesia.
- Late: One out of four cases develops pneumonia. Those who form atelectasis are especially at risk.

Rebleeding

Monitor the drains closely. The sources of rebleeding are normally minor vessels close to the stomach (short gastric arteries). Reoperate without delay.

Abscess formation

A hematoma under the left diaphragm (insufficient drainage) and a missed colon injury (insufficient exploration) cause abscess formation under the left

diaphragm. Injury of the tail of the pancreas normally causes retroperitoneal abscess formation. Anyhow, the clinical signs are a worsening general condition, intermittent temperature peaks ("abscess temperature") – and sometimes a dull pain referred to the left shoulder area. The management is exploratory laparotomy without delay. Wash out the abscess with warm normal saline. Inspect the pancreas and drain pancreatic wounds. Arrange double dependent tube drainage from the infected area.

Tendency to attract infections

The spleen is part of the body immune system. Pneumococcal and other infections may rise after splenectomy. Give prophylactic antibiotics for one month after splenectomy. If available, give pneumococcal vaccination to all splenectomy cases.

Points to note – Chapter 31

The diagnosis is often missed
- note the clinical signs: p. 416
- know how to do diagnostic peritoneal lavage: p. 109

Study the anatomy
- pancreatic injuries may bleed, note the localization of the splenic, and the inferior mesenteric vessels: p. 416
- note the localization of the pancreas – inside the "lesser sac", behind the peritoneum: p. 364. Know how to explore it: p. 363
- associated injuries to other abdominal organs are common: p. 392

In most cases the primary management is simple
- control bleeding by gauze packing: p. 365
- drain the pancreatic wound, but do not suture it: p. 417

31 Injury to the pancreas

Surgical anatomy

The mortality rate after pancreatic injury is high – one out of five – mainly due to associated injury to major vessels. Another factor contributing to the high mortality rate is diagnostic difficulties:

Retroperitoneal location – delay of symptoms!
The most common mistake in pancreatic management is to miss the injury initially: The clinical signs from associated injuries dominate the picture, the early signs indicating the pancreatic injury are few. The pancreas is covered by peritoneum, and located inside the "lesser sac". Minor and moderate injuries may therefore grumble with poor clinical signs for days, before signs of pancreatic rupture develop:

- Central abdominal pain
- Referred back pain
- Vomiting
- Worsening general condition
- Peritonitis

Explore the pancreas on suspicion
If the stomach, duodenum, spleen or left kidney is injured, make it a routine to also explore the pancreas. Early drainage of pancreatic tears is essential. Late surgery is often unsuccessful.

The pancreas consists of glandular tissue covered with a thin fibrous capsule. The hold for sutures in the capsule is poor, especially if surgery is delayed. The entire organ is located behind the peritoneum on the posterior abdominal wall. The pancreas produces digestive enzymes. The pancreatic juice is highly irritating to the tissues, and leaking from pancreas will create local inflammation, soft tissue necrosis and formation of local abscess, fistula or cyst. Leaking of pancreatic juice into the peritoneal cavity may cause erosion and damage to other structures. Retroperitoneal tears may cause retroperitoneal abscess on the posterior abdominal wall.

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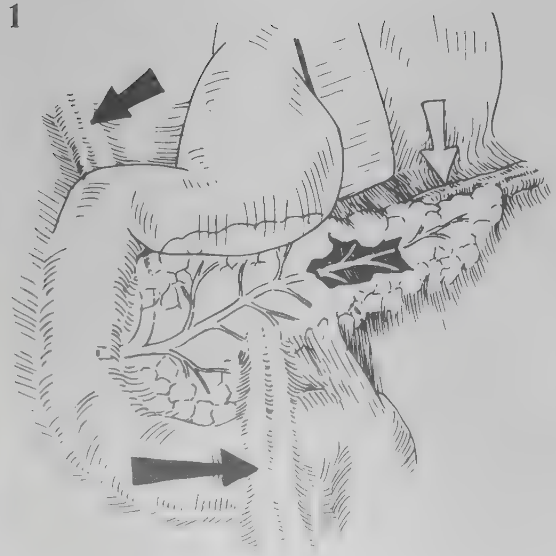


1 The anatomy: The central duct of the pancreas empties into duodenum together with the main bile duct (short black arrow). Note the multiple side ducts inside the pancreas. Torn pancreatic ducts should be carefully ligated to avoid free leak of the pancreatic juice. Lacerations of the main duct: Resect the part of pancreas to the left of the tear. The splenic artery (white arrow) runs at the upper border and the vein behind the pancreas. As both splenic vessels give several branches to the pancreas, splenectomy should be done as a routine in resections of the pancreatic tail. The superior mesenteric artery (long arrow) runs through the body of pancreas. The main blood supply for the pancreas is from branches of the duodenal artery. The pancreatic blood circulation is thus based on a rich network of collaterals: So only major tears and obviously necrotic areas should be debrided.

Pancreatic injury

Associated injuries

Of ten cases with pancreatic injury, more than five cases have associated serious injury to other abdominal organs. In most cases, the associated injury has priority over the pancreatic injury:
- Injury to major vessels: Control bleeding. Consider reconstruction.
- The colon: Close perforations and divert the fecal stream
- The spleen: Control bleeding by splenectomy
- The liver: Control bleeding
- The kidney: Control bleeding

Then explore the pancreatic injury.

The exploration

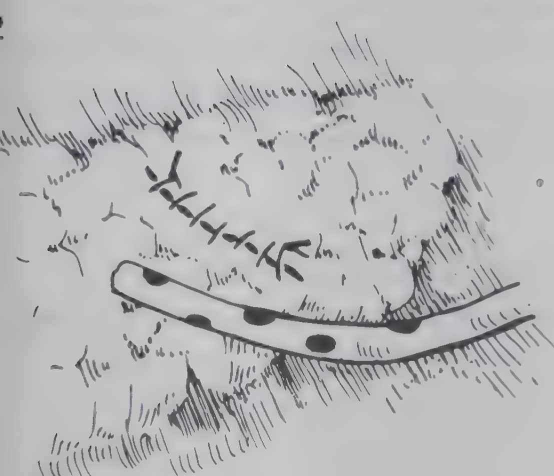
Retract the transverse colon downwards and the gastro-colic ligamentum to the left. You can then inspect the duodenum and the head of pancreas. To inspect the body and tail of pancreas, split the gastro-colic ligamentum (p. 363). To explore the posterior surface of the pancreas, mobilize the duodenum together with the head of pancreas (Kocher's maneuver: p. 364). You may also mobilize the body of pancreas by splitting the peritoneum along the lower border, and lifting the organ off the posterior abdominal wall by blunt dissection.

The emergency laparotomy: p. 155.

Emergency surgery: Control the bleeding – hands off the pancreas.

Free leaking of pancreatic juice may complicate other abdominal injuries. Drainage is thus the essential part of the pancreatic injury management – a simple and rapid procedure that should be done if possible also during emergency laparotomies. The pancreatic fistulas that often develop along the drain are seldom a serious complication, most fistulas heal spontanously.

- Intraperitoneal bleeding: There is no time for extensive pancreatic surgery during an emergency laparotomy. Try to place a large-bore drain at the pancreatic wound. If that is not possible due to gauze packs, better leave the pancreatic injury unmanaged until a second-look laparotomy after 24-48 hours.
- Retroperitoneal bleeding: Do not enter a retroperitoneal hematoma unless it is expanding. A possible retroperitoneal pancreatic tear is no indication to mobilize the pancreas as that will cause a dramatic and maybe fatal bleeding. Apply drainage and delay the pancreatic exploration until the second-look laparotomy.



2 **Most important: Drainage.** Minor tears into the pancreas: Explore the wound, apply drainage but do not suture the tears. Major tears should be debrided and closed: First identify the main ducts and close them with separate ligatures. Then close the tear with superficial interrupted sutures through the pancreatic capsule (non-absorbable, non-cutting needle). Do not tie the sutures

tightly – they will just tear the loose pancreatic tissues. Suture an omental tag to the wound to supplement the closure. **Note:** Fistulas may develop along the drain; pancreatic juice may erode abdominal structures. Locate the drain so it does not come in contact with major vessels and other vulnerable structures.

3

3 **Extensive injury:** Resect the part of pancreas to the left of the tear. Note the ligatures on the splenic artery and vein: You have to mobilize and remove the spleen in order to do the pancreatic dissection. The pancreatic incision is done in a fishtail fashion. The main pancreatic ducts are ligated and the incision closed by just capsular sutures. Fashion a strand of omentum with a few sutures to cover the pancreatic suture line (p. 403).

Consider enteral feeding: Protracted recovery and a long period of intestinal paralysis are common after a major pancreatic injury. Cases with associated injury to the stomach and duodenum especially profit from high-energy enteral feeding and duodenal decompression from the first day after surgery.

Complications of injury and surgery

Local peritonitis and abscess formation

The reasons are poor drainage and leaking of free pancreatic juice behind the peritoneum or into the abdominal cavity. Or missed diagnosis with necrotic pancreatic tissue left over from the primary surgery. Reoperate without delay:

- Drain: The tissues are swollen and dissections will be bloody. Avoid any surgical manipulation, just wash out the abscess and arrange proper drainage.
- Enteral feeding: Probably the rehabilitation will be protracted, the risk of secondary organ complications is high. Arrange enteral feeding (gastrostomy or jejunostomy).

Post-operative bleeding

Probably the reason is bleeding from some associated injury. Also consider erosion of some vessel due to leaking of pancreatic juice. Reoperate without delay.

Pancreatic fistula

Diets for enteral feeding: p. 610.

If the drain produces pancreatic juice, a fistula is established. The fistula may also empty directly into the gastro-intestinal tract. Change a small pancreatic drain for a large-bore one. Protect the skin from the irritating pancreatic juice (enterostomy bag). Enteral feeding with solutions rich in glucose will reduce the pancreatic secretion. Most fistulas heal spontaneously after some time.

Post-traumatic pancreatitis

Pancreatitis is a rare complication that may develop within the first week after injury. The clinical signs are those of a local peritonitis, and the diagnosis should be verified by surgical exploration: There is a general edema of the pancreas, but no necrosis or abscess formation. The management is conservative: n.p.o. and enteral feeding. The mortality rate is high.

Points to note – Chapter 32

Do not miss the injury

- there may be few clinical signs, and no blood in the urine: p. 422
- in blunt injuries without circulatory shock, you may delay the surgery. Collect samples of urine every hour to see if the bleeding becomes less: p. 424

Study the anatomy

- note which organs are close to the right kidney: p. 392. Know how to expose the right kidney: p. 422
- note which organs are close to the left kidney: p. 392. Know how to expose the left kidney: p. 423

The emergency management of bleeding cases is simple

- make a midline laparotomy: p. 356
- gauze pack the kidney wound and the kidney compartment. But do not enter a retroperitoneal hematoma: p. 424

Normally the kidney is lost if the ureter injury is missed

- there are few clinical signs in ureter injuries: p. 425
- X-ray urography is diagnostic
- surgical repair of the ureter is urgent. But leave it for the experienced doctor

32 Injury to the kidneys

Surgical anatomy

Surgery should be conservative
The kidney blood perfusion is copious. The kidneys normally heal well after major injuries. The necrosis after high-energy missiles is not as extensive as you may see in muscle tissue wound tracks.

Wide wound tracks and heavy bleeding
The renal tissue is solid and non-elastic. It responds to missile injuries as do muscle tissues:: Low-energy missiles cause narrow wound tracks. High-energy missiles or heavy blunt injuries may cause extensive and bleeding tears deep into the renal tissue. The main concern in emergencies is to control bleeding – the exploration and wound management should be left for a second-look laparotomy.

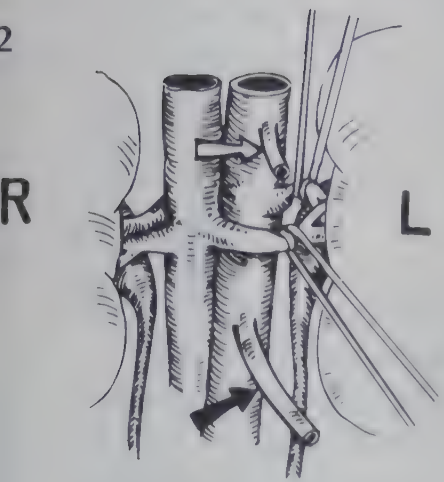
There may be few clinical signs
- Negative peritoneal lavage: The kidneys are packed with fatty tissue inside a compartment where the walls consist of the peritoneum and the abdominal organs in front, and the abdominal wall lateral and posterior. Major hematomas may collect inside the renal compartment with few early clinical signs except increasing circulatory shock. Often the peritoneal lavage is negative.
- No hematuria: Hematomas may form under the renal capsule and are retroperitoneal without leaking into the collecting system. In one out of five kidney injured there is no hematuria.

1

1 **Exploration of the right kidney – relation to other organs:** The exploration of the kidneys is always done through the midline laparotomy incision. The lateral approach common in elective renal surgery is risky: You may enter a bleeding retroperitoneal hematoma without being able to control the renal vessels at the hilum of the kidney.
- Major bleeding: Do not enter the right kidney compartment without first taking control of the renal vessels. Mobilize the duodenum by Kocher's maneuver and identify the hilum of the kidney with the renal artery and vein (p. 364). Then explore the kidney as illustrated here.

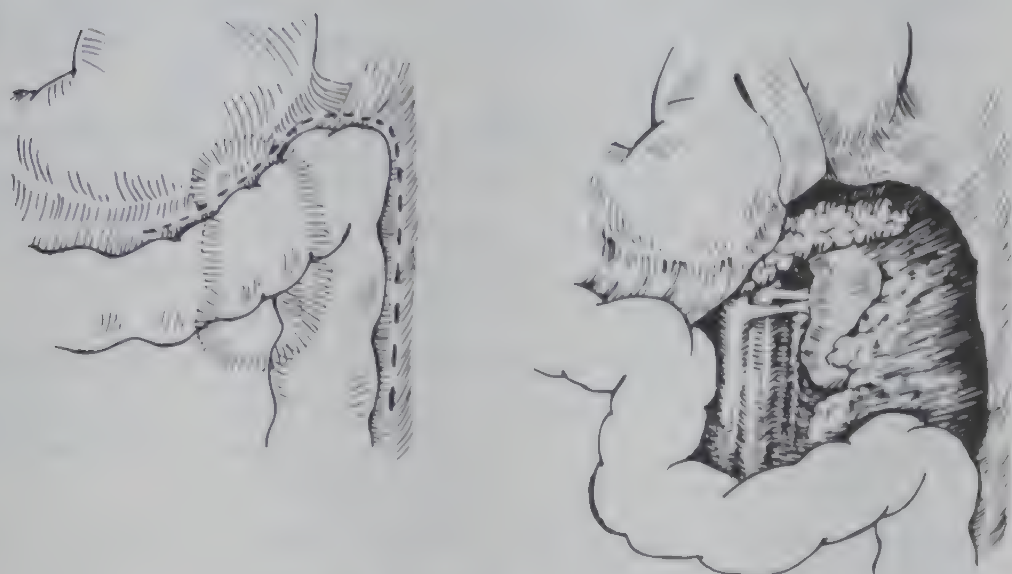
- Stable case: The exploration starts with mobilization of the right colon through the standard lateral peritoneal incision. (Also see p.362) Extend the incision along the duodenum (dotted line) to free the hilum of the right kidney.

2



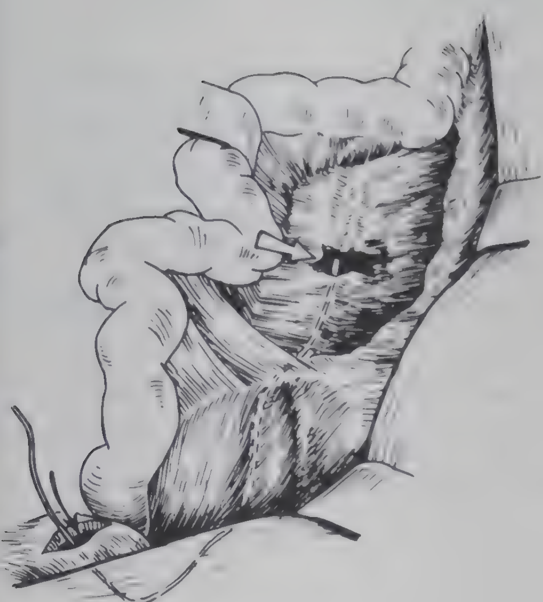
2 **Major bleeding – first control the renal artery and vein:** The arteries leave the aorta just proximal to the veins. Note the right renal artery running behind the caval vein. The incision for direct exposure of the **left** renal hilum: ill. 12 on p. 362. By rubber bands or "finger clamping" you can control the circulation to either kidney. Temporary occlusion of the renal vessels should not last for more than ten minutes – then release the occlusion for some minutes before you repeat the procedure. Black arrow: the inferior mesenteric artery. White arrow: the superior mesenteric artery.

3



3 **Exploration of the left kidney – relation to other organs:** Retract all the small intestine to the right. In case of bleeding renal injury, first control the renal vessels (p. 364). The kidney is normally explored by mobilizing the left colon flexure by the standard lateral peritoneal incision. By blunt dissection the colon is retracted medially and downwards. **Note:** Careless dissection may tear the peritoneal ligaments between the spleen and the left kidney and cause bleeding. The kidney is covered by a fascia and a pad of fat. The upper part is covered by the tail of pancreas – take care not to tear it.

4



4 **Exploration of the ureter:** Both ureters are located on the posterior abdominal wall just medial to the right/left colon. A rupture of the ureter (arrow) is exposed by mobilization of the (right or left) colon. The ureter catheter inserted from the bladder shows the localization of the ureter. The anatomy of the pelvic part of the ureters: Study p. 435 and 447.

Injury to the kidney

Associated injuries

Eight out of ten patients with missile injury to the kidney also have injuries to other abdominal organs. Most common is colon injury. As the kidneys belong to the upper part of the abdominal cavity, the diaphragm, liver, duodenum, pancreas and spleen should also be explored for injury.

Blunt injury
As the kidneys are well protected inside the renal compartment, blunt injuries are seldom extensive. Collect urine every hour for 24 hours and monitor the degree of hematuria. Only circulatory unstable cases and cases with increasing hematuria should be explored by a midline laparotomy.

Emergency management

The emergency laparotomy is done on vital indications – there is no time for X-ray urography or other elaborate diagnostic procedures.

- **Insert a bladder catheter:** Hematuria indicates injury to the kidney. Absence of hematuria does not exclude injury to the kidney.
- **Midline incision:** In most cases the source of bleeding is not the kidney injury, but some associated injury. Control the bleeding by aortic compression and/or gauze packing. Leave the kidney without exploration unless it is obviously bleeding.
- **Heavy bleeding from one kidney:** Pack gauze pads and apply compression towards the bleeding renal compartment. If gauze packing does not control the bleeding, compress the aorta proximal and distal to the renal arteries (p. 365). Split the peritoneum and control the renal artery and vein before you explore the kidney.
- **Retroperitoneal hematoma:** Monitor the hematoma for some minutes. Hands off unless the hematoma expands rapidly. If you have to explore the hematoma, first control the renal vessels and be prepared for circulatory collapse when you split the peritoneum.
- **Moderate kidney injury:** Pack both the renal wound and the compartment with gauze, leave the drain, and re-explore after 24-48 hours.
- **Extensive kidney injury – experienced surgeon:** Consider primary nephrectomy – resections and suture of the kidney wounds are more bloody and time consuming. In multi-organ injured, nephrectomy cannot be done within the one-hour limit, and should be delayed until the second-look laparotomy when the patient is circulatory stable. If necessary, tie the renal vessels during the emergency laparotomy, pack the kidney – and remove it after 24 hours.
- **Extensive kidney injury – inexperienced surgeon:** If the renal vessels are not torn, pack the kidney. Re-explore and arrange drainage after 24-72 hours. If the renal vessels are torn, tie them and refer the case for nephrectomy.

The emergency laparotomy in detail: p. 155.

The one-hour limit in emergency laparotomy: p. 133.

Preparations for surgery – stable cases

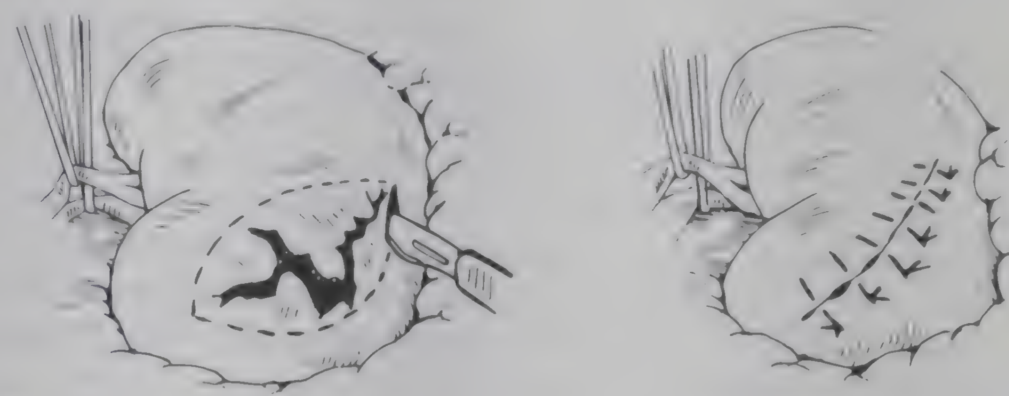
- Do i.v. contrast urography: Most important – is the opposite kidney normal without delayed excretion of contrast? Assess the injury: Leaking of contrast may identify a renal tear or rupture of the ureter. Renal sectors with less concentration of contrast indicate exploration.
- The urine examination: In cases with hematuria and good vital signs you have enough time to collect and monitor samples of urine every hour for some hours. Samples that change from red towards brownish color normally indi-

Tuberculosis is a common cause of chronic renal failure.

cate reduced bleeding. The absence of hematuria does not necessarily imply that the kidney has escaped damage. Also hematuria may show up as late as 24 hours after injury.

5 Debridement and primary suture: Note that as exploration of the tear may provoke rebleeding, the best alternative may be the simplest: Drain only. During the debridement, major vessels and urinary ducts are tied with ligature upon small curved needle. Provided all necrotic tissue is debrided, the wound is closed with deep, interrupted hemostatic mattress sutures. If the sutures do not control the bleeding, release them and apply patches of crushed muscle or a tag of omentum into the wound before closure. Decompress the kidney (nephrostomy – ill. 8) and let a large-bore tube through a separate stab incision in the lateral abdominal wall drain the renal compartment. Replace the colon, close the peritoneal incision and apply another dependent drain from inside the abdominal cavity.

6



6 Partial resection: Renal resections are bloody, and should not be done in unstable cases. Nephrectomy is technically more simple and safe. A major tear of the upper or lower pole of the kidney may be managed by guillotine resection and closed with flaps of the renal capsule. Elsewhere a wedge-resection of the tear may be done. For safety, first control the renal vessels at the hilum. The resection is done by stepwise sharp incision and ligature of the vessels and urinary ducts. Arrange a tube nephrostomy (ill. 8) before the resection is closed.

Injury to the ureter

jury to the pelvic part of the ure-
rs: p. 435.

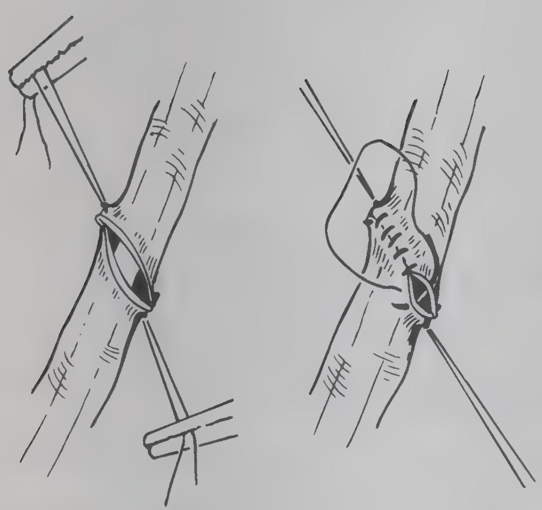
Missed diagnosis
The early clinical signs of isolated injury to the ureter are few or none. Only days after the injury the retroperitoneal collection of urine may cause low abdominal swelling, pain and visible urinary phlegmon. At that time the kidney may be lost due to urinary obstruction. As the management of ureteral injury is technically simple, the missed diagnosis is a catastrophe.

Surgical exploration on suspicion!
X-ray urography is an unreliable diagnostic tool: The X-ray performance of the ureters is often poor and non-continuous. Also a partial obstruction of the ureter the day of injury may gradually become complete when the urinary phlegmon and hematoma add to the obstruction. The only safe strategy is surgical exploration in all cases where the wound track is close to the ureter.

Ureter – or a torn vessel?
Pinch the structure and see if it contracts as the ureter will.

Accidental damage during surgery
Careless exploration and ligatures are a common cause of ureteral tears and obstructions. The risky procedures are mobilization of right or left colon, right hemicolectomy, exploration of rectal wounds, exploration of iliac artery injury and surgery on the female organs. During those procedures the ureter should always be identified.

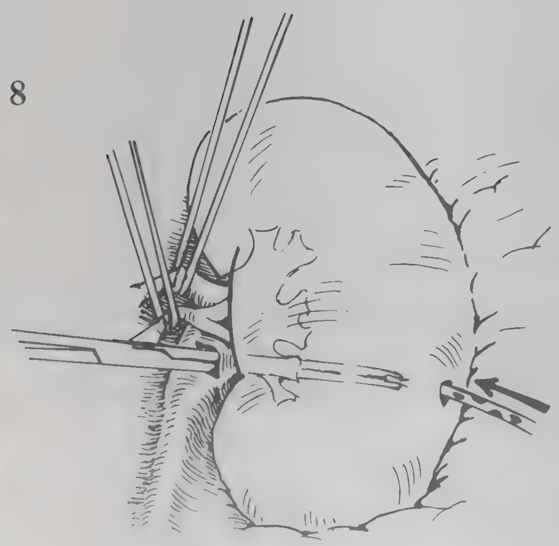
7



7 Reconstruction of the ureter: Close intestinal wounds before you expose the ureteral tear. First open the bladder (p. 435) and pass a ureter catheter (you may use a thin plastic suction tube) up the ureter to the site of injury. Incise the peritoneum, debride the wound track and trim the ragged ends of the ureter. A transverse anastomosis may cause secondary stenosis: Make a short longitudinal split at both ends of the ureter to achieve an oblique anastomosis. Bring forward the catheter across the tear up to the kidney. Apply one anterior and one posterior stay suture, and fulfill the anastomosis with one-layer interrupted or continuous sutures (4-0 absorbable, silk or polypropylene). Do not perform the anastomosis under tension: Mobilize the ureter proximal and distal to the anastomosis. Ensure that the wound edges are everted all the way round the anastomosis. Apply a tube drain beside the anastomosis and close the peritoneum. The ureter catheter is delivered through the urethra together with a Foley bladder catheter. The bladder incision is closed. Leave the ureter catheter for two weeks, then pull it out carefully and stepwise.

If the damage is extensive and the ureteral ends cannot be approximated, tie the ureter proximal and distal to the injury and drain the urine by a temporary catheter nephrostomy (see below).

8



8 Decompression of the collecting system – catheter nephrostomy: Wound edema, hematomas and ureter obstructions may impair the flow of urine and increase the pressure inside the collecting system. Suture lines may rupture and urine penetrates renal tears. Indications for nephrostomy:

- All more than minor renal tears.
- Tears of the ureter that cannot be reconstructed.
- In cases where you may suspect injury to or compression of the ureter (retroperitoneal hematoma or abscess).
- As drainage in cases with renal infection and abscess formation after injury.

Expose the kidney and control the renal vessels before you open the renal compartment. Cut several side holes in a small-caliber Foley catheter and

insert it through a stab incision in the lateral abdominal wall. Make a small incision in the renal pelvis. Guide thin forceps carefully through the inferior urinary duct (calyx), through the renal tissue towards the renal capsule. Make a small stab incision in the capsule and "railroad" the Foley catheter into the renal pelvis. Thrust it well into the ureter, but see to it that there are several side holes draining the pelvis. Fix the catheter well: The patient may carry it for weeks unless it slips out. **Note:** Pass the catheter through the inferior calyx as that track bleeds less, and the direction lets you take out the drain below the costal arc.

Complications of injury and surgery

Rebleeding

Autotransfusion: p. 270.

- Within 24 hours: The reason may be hemodilution with low platelet counts – consider autotransfusion or transfusion of fresh whole blood. The reason may also be poor control of bleeding during the primary surgery, the wounds start bleeding when the organ perfusion is established by post-operative volume therapy. Reoperate without delay; identify and control the bleeding points. Consider temporary percutaneous gauze tamponade (p. 366).
- Rebleeding 4-5 days after the injury: The reason is probably wound infection. Reoperate under antibiotic cover. Handle the tissues with care: Extensive dissection in infected tissue will increase the bleeding. First control the renal vessels, then explore the wound, open sutures, wash out the abscess and control the bleeding by gauze packing.

Leaking of urine

Urinary phlegmon of the pelvic cavity: p. 110.

The reason is poor decompression of the kidney or a missed ureteral tear. X-ray urography may identify the leaking site. If the leakage is moderate and with no signs of infection or abscess formation – wait and see: The leak often closes spontaneously. If the leak is considerable with swelling of the abdominal wall, reddish skin and pain – reoperate: Check that the nephrostomy is functioning. Explore the posterior abdominal wall for urinary phlegmon. If you cannot identify and repair the leak, and X-ray facilities are not available, drain the renal compartment and the retroperitoneal space with several dependent drains.

Renal abscess

Tenderness and swelling of the lateral abdominal wall, worsening of the general condition, and peaks of fever indicate abscess formation. Reoperate without delay:

- Identify the abscesses: There may be more than one (p. 461). Also consider retroperitoneal abscess formation inside the pelvic cavity.
- Mobilize and explore the colon, including the posterior intestinal wall. Probably a perforation was missed during the primary surgery.
- Explore the kidney for localized swelling under the renal capsule indicating abscess formation. Or areas of soft consistency indicating renal necrosis.

- If nephrostomy was not done during the primary surgery, do it now.
- Wash out the abscesses with warm normal saline. Drain both the peritoneal cavity and the retroperitoneal space with several large-bore dependent drains.

Poor renal function

If X-ray facilities are available, control urography should be done 24-48 hours after the primary surgery. Normally the function of an injured kidney is temporarily decreased. The reason is edema of the tissues due to the injury itself, and due to hypoxia/circulatory shock. If the other kidney is normal, do not bother. No function of the injured kidney indicates surgical exploration.
Several reasons should be considered:

- The nephrostomy is not functioning. A bend on the catheter may be managed by pulling the catheter slightly. If the nephrostomy still does not produce urine – reoperate without delay.
- A missed injury to the ureter: Reconsider the wound track – could the ureter be damaged? Reconsider the surgery – could the ureter be torn or trapped in a ligature?
- Stenosis to the ureter: A partial stenosis of the ureter after reconstruction is not uncommon. Try to pass a fine-caliber ureter catheter from the bladder through the stenosis. If that does not succeed, do nephrostomy.
- Renal necrosis due to hypoxia: 30-60 minutes without blood perfusion may permanently destroy the kidney. In cases with multi-organ injury and grave circulatory shock that do not respond to volume therapy, hypoxia may destroy a kidney. The more so if the kidney itself also was injured.

Points to note – Chapter 33

Study the anatomy
- note the close relationship between the bladder and rectum: p. 376. And uterus: p. 477. Combined injuries are common, take special care not to miss a rectal injury.
- note the compartments and spaces around the bladder and the rectum: p. 432 and 433. Drain these compartments: p. 436 and 454

The bladder and the rectum may be damaged in several ways
- from below by mine shrapnel penetrating the pelvic floor: p. 84
- from bullets penetrating the pelvic wings: p. 469
- from displaced bone fragments in pelvic fractures: p. 470

The primary management of bladder injuries is simple
- first, insert a urethra catheter to the bladder. But do not force it: p. 436
- then, make a low midline laparotomy, and insert a suprapubic catheter to the bladder: p. 436
- then, close the bladder wound to prevent leaking of urine, and drain the compartments around the bladder: p. 432

The emergency management of urethral injuries
- posterior urethral injury: p. 433. Insert suprapubic bladder catheter through a small laparotomy: p. 436. And leave the urethral repair for an expert doctor
- anterior urethral injury: p. 433. Do marsupialization: p. 437

33 Injury to the urinary bladder and urethra

Surgical anatomy

Bladder and urethral injuries are common wartime injuries

- Mine injury: Even tiny shrapnel may cause extensive tears of the urethra, the retroperitoneal parts of the bladder and rectum. The lower limb injuries dominate the picture, and urinary tract injuries are often missed at the time of primary management.
- High-energy missiles: The bone of the pelvic wings does not protect against penetrating missiles. Combined injuries to the small intestine, the rectum and the bladder are common.
- Blast wave injury: Partial and total ruptures of the bladder are seen.
- Blunt pelvic injury: Fracture fragments may tear the bladder and the posterior parts of the urethra. High-energy injuries may cause wide blow-out-like tears of the bladder.

The spalling effect: p. 82.

The main problem: retroperitoneal abscess formation

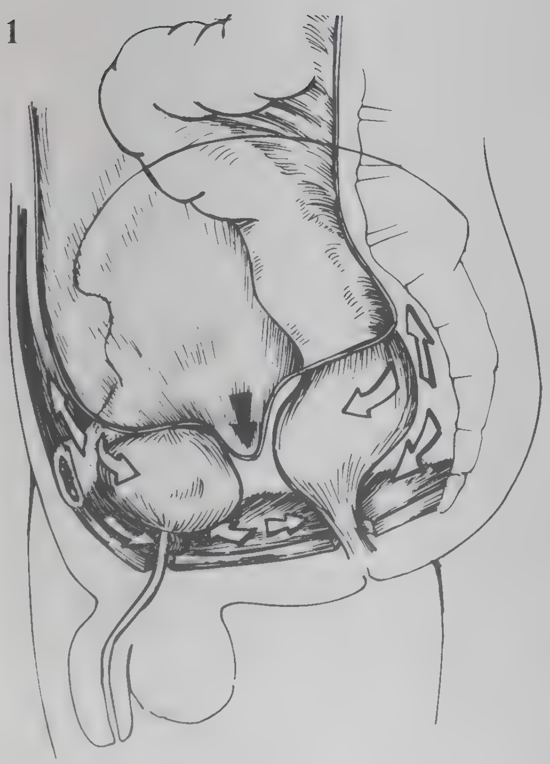
Three factors contribute to the high risk of abscess formation:

- The bladder and urethra are retroperitoneal organs. In most cases urine and blood leak into the retroperitoneal space – and not into the abdominal cavity.
- Inside the pelvic cavity are several retroperitoneal spaces and compartments where considerable amounts of urine and blood may collect – with few early clinical signs.
- Hematomas and urine phlegmons become infected from associated rectal injury or from outside through the skin inlet wound.

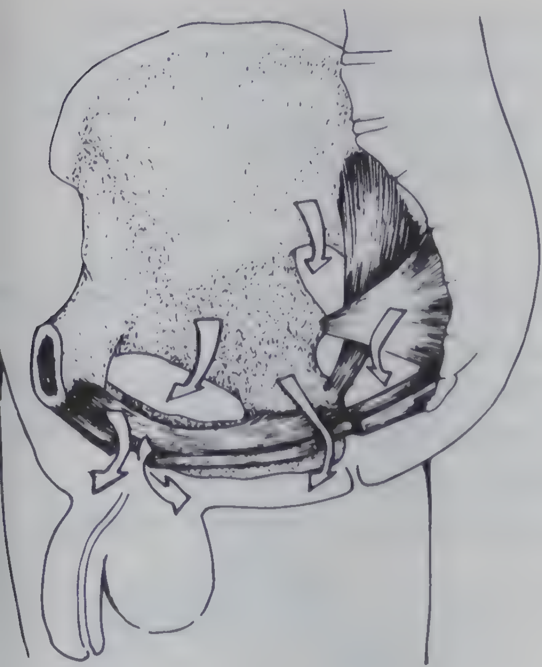
The essentials of the management

- Drain the retroperitoneal space: Study the pelvic anatomy carefully to explore the compartments where abscesses normally form. Drain these compartments with large-bore dependent drains.
- Decompress the urinary tract: Increased urinary pressure causes leaking of urine. Even a partial obstruction causes damage to the kidneys. Routine: suprapubic bladder catheter **and** the urethra catheter.

1

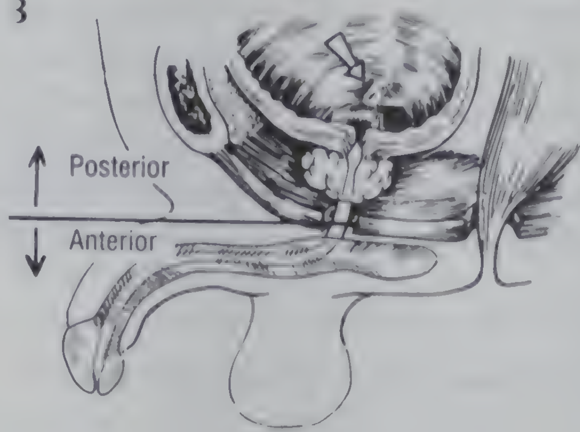


1 Compartments inside the pelvic cavity: The lower part of the abdominal cavity is located inside the pelvis. Thus missiles penetrating the pelvic wings may cause injury to the small intestine, colon and rectum. Peritoneal hematoma and abscess often collect in the rectovesical/rectovaginal pouch (black arrow). The pouch may be drained via the vagina in women or by drains along the rectum to the perineum (p. 387). Outside the peritoneum hematomas may collect in the loose connective tissues in front of and lateral to the bladder (white arrows), and lateral and posterior to the rectum up along the spine to the posterior abdominal wall. Abscesses often sink down and collect above the muscular diaphragm that constitutes the floor of the pelvic cavity. **Notice:** The upper parts of the bladder are covered by peritoneum. You may thus enter the bladder either through the abdominal cavity, or by blunt retroperitoneal dissection behind the pubic bone.



2 **Compartments outside the pelvic cavity:** Hematomas and abscesses inside the pelvis may penetrate through several "windows" along with vessels and nerves into the buttocks and thigh. Through the pelvic diaphragm they may penetrate into the perineum, penis and scrotum. Local swelling of these structures may be the first indication of complications.

3



3 **The male urethra:** The management depends on whether the injury affects the anterior or the posterior part of the urethra. The posterior part consists of urethra above the pelvic diaphragm. The anterior part of urethra runs inside the spongious body of penis.

ternative exploratory incisions:
ne external iliac artery – p. 477
ne buttock – p. 473 and 480

Types of injury

Missile and mine injuries

The main problem is associated injuries, not the urinary tract injury. In cases with upper thigh, perineal, pelvic or lower abdominal missile wounds, the indications for midline laparotomy are

- Internal bleeding – circulatory shock: The common source of heavy bleeding is the pelvic venous network (p. 469).
- Loss of the femoral pulse beat: Suspect injury to the iliac artery.
- Rectal tear: Identify the tear by manual exploration. Primary diversion sigmoidostomy (p. 384) reduces the risk of pelvic abscess formation.
- Hematuria (bladder catheter is diagnostic): Identify the injury/injuries.
- You cannot pass the bladder catheter. You may feel a high-riding prostate by finger exploration of the rectum: There is probably a posterior tear of the urethra (p. 437). Exploration and suprapubic drainage are necessary steps.

The priorities during the primary surgery: (1) Control the bleeding and start volume therapy. (2) Close intestinal wounds and divert the fecal stream. (3) Manage the urinary tract injury.

Blunt injuries

Such injuries to the bladder are common. Displaced pelvic fractures may cause tears of the bladder and the posterior part of the urethra. Also the bladder may rupture in a blow-out fashion with wide tears. In circulatory unstable cases, urgent laparotomy is done (see Emergency management). Unless there are signs of rectal injury, you may delay the primary surgery in other cases:

- Collect samples of urine every hour to monitor if the bleeding persists or decreases. Brownish coloration normally indicates less bleeding.
- Do X-ray cystography: Instill 200 ml contrast through a bladder catheter, shoot one film before voiding and one after. Explore urethral tears or

obstructions. Minor tears of the bladder may close spontaneously within 48 hours. Minor leaks persisting after 48 hours may be managed by suprapubic bladder catheter and retroperitoneal dependent drains outside the bladder. Major leaks should be explored, debrided and closed.

Urethral injuries
If the urethra cannot take a bladder catheter, it means the continuity is broken: There is either a tear or stenosis due to external compression (injury to the penis, hematoma). **Note:** Injury to the urethra does not exclude injury also to the bladder. A missile or a pelvic bone fragment may well tear both structures.
- Open injury: Do primary reconstruction or marsupialization (ill. 8).
- Closed injury: Insert suprapubic bladder catheter (small midline incision).

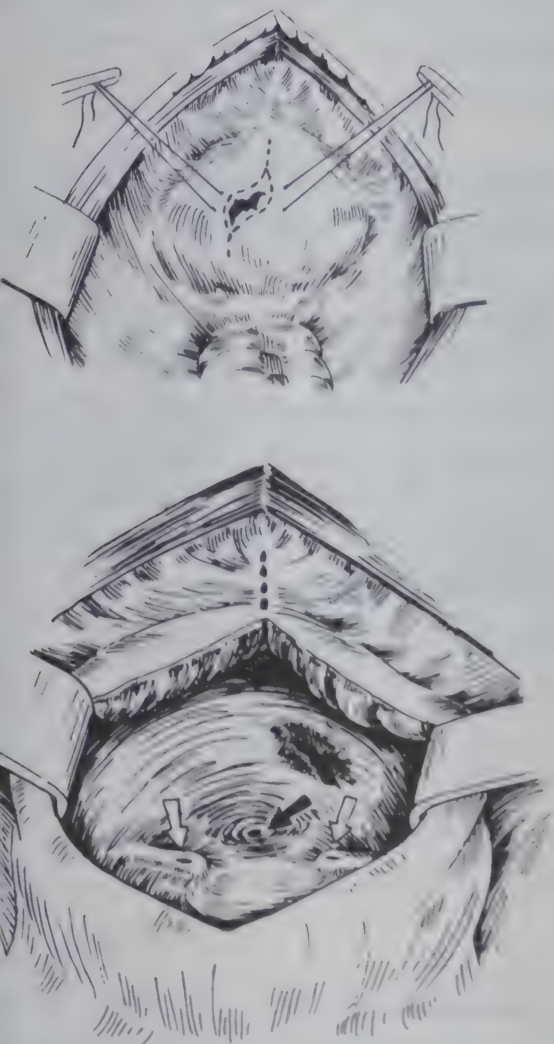
Secondary reconstruction is done 3-6 months after the injury.

Emergency management

High-energy pelvic injury – blunt or penetrating – may cause heavy internal bleeding. Emergency laparotomy with compression/clamping of the distal aorta should be done if there is no response to intensive volume therapy. Especially if blood transfusions are not available, early aortic compression may save life.
- **Prepare transfusions:** Collect the blood during surgery; you may use it for autotransfusion unless there is a major intestinal injury. Blood-type and order fresh whole blood if available. In hemodiluted cases, the transfusion of blood platelets is more important than surgery.
- **Aortic compression:** Midline incision, retract the small intestines upwards and out of the abdomen. Compress the distal part of the aorta against the spine. Let assistants compress the femoral arteries at the groin to reduce arterial back-flow. Start transfusions. You may maintain the aortic compression/clamping continuously for 60-90 minutes.
- **Intraperitoneal bleeding:** Pack the bleeding quadrant (p. 360) with large gauze packs. Major vascular injury: Consider ligature (p. 367). Close the abdomen without drain. Do not drain the retroperitoneal space. Reoperate after 24-48 hours: Remove the gauze packs, explore and manage the urinary tract injuries as discussed below.
- **Retroperitoneal bleeding:** If the peritoneum is not torn, do not enter a retroperitoneal hematoma: Bleeding will increase and the circulation will collapse. Maintain compression on the aorta and the femoral arteries. Continue the volume therapy. Pack the rectovesical pouch and both lower quadrants with gauze under manual compression: Increased pressure inside the hematoma may reduce/stop the bleeding. Transfusion of fresh whole blood is life saving.
- **Rectal injury:** Note the one-hour limit (p. 133) – there may be no time to do intestinal surgery or enterostomy. You may tie a band around the sigmoid colon to stop the fecal stream. Dilate the anus to drain the rectum of feces.
- **The urinary tract injury:** Insert a bladder catheter by the urethra or suprapubic to monitor the volume therapy. Leave the urinary tract surgery for the second-look laparotomy after 24-48 hours.

The emergency laparotomy in detail: p. 155.

Injury to the bladder

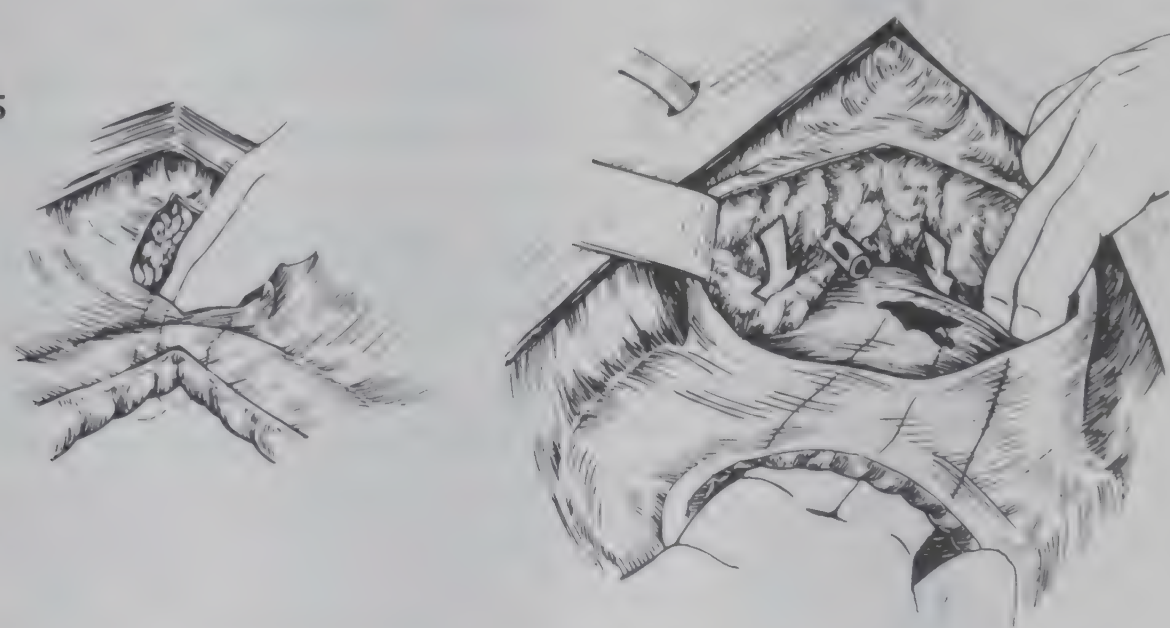


4 Intraperitoneal exploration of the bladder: The standard exploration of the bladder is done from the abdominal cavity through a longitudinal bladder incision. Note the relatively thick bladder wall, consisting of three layers: Innermost is the mucosa, rich in blood vessels – even small tears may bleed considerably. Then the thick muscular layer, and outside a thin capsule.

In this case a missile bladder wound is debrided between stay sutures. As the bladder blood circulation is copious, the debridement is generally moderate. Brisk bleeding during the debridement is controlled by a tight bladder suture when the incision is closed. As double wounds are common (inlet-outlet) the wound is extended to make an exploratory incision.

Insert retractors, and inspect the base of the bladder. Note the triangle with the urethral outlet (black arrow) and the openings for both ureters (white arrows). Verify by direct vision that clear urine is pouring from both ureteral openings: Flush the infusion for some minutes to increase the urine production. A "dry" ureteral opening indicates injury to the ureter: It should be managed and a ureter catheter passed before you close the bladder (p. 423). In this case the other bladder wound is located on the anterior retroperitoneal surface of the bladder. It should be explored and drained from outside the bladder – the dotted line represents the exploratory incision.

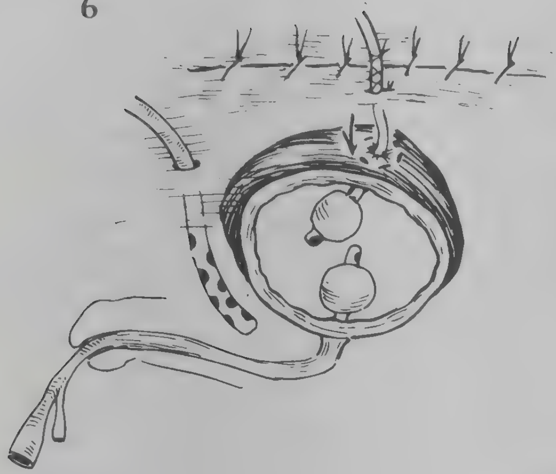
5



5 Extraperitoneal exploration and drainage of the bladder: Extend the midline abdominal wall incision until it reaches the pubic bone. Split the peritoneum in the midline between the bladder and the pubic bone. By blunt dissection, wipe the fatty tissues in front of the bladder off the bladder wall. You have now entered one of the retroperitoneal compartments of the pelvis where hematomas and abscesses may form (ill. 1). Do not explore deep hematomas in this compartment (arrows) as deep dissection may cause heavy bleeding. Insert large-bore tube drains with side holes through separate lateral stab incisions in the abdominal wall; guide the drains outside the peritoneum into this compartment. The bladder is explored with one hand inside, one hand outside the bladder wall. In this case there is a tear of the bladder at its neck. Close the

bladder wounds with continuous interlocking sutures that include all three layers of the bladder wall (absorbable 3-0 on a well-curved needle). Most bladder wounds are best closed from outside the bladder as "blind" deep sutures from inside the bladder may trap the ureter or urethra.

6



6 **Drainage and decompression of bladder injuries:** More than minor tears should have double decompression of the bladder – suprapubic drainage in addition to the urethral bladder catheter: Despite intermittent flushing through the catheters with normal saline, bleeding may clot one catheter. Use a large-bore Foley bladder catheter also for the suprapubic decompression. Insert it through a separate stab incision of the lower abdominal wall and the bladder wall (not through the exploratory incisions). A purse-string circular suture around the catheter prevents urinary leak. Also tube drains are inserted well down along both sides of the bladder and brought out through separate lateral incisions. In uncomplicated cases the urethral catheter and the dependent drains are removed after 4-5 days, but the suprapubic bladder catheter is left for two weeks.

Injury to the urethra

Anterior injury – conservative management: Never force a bladder catheter to pass a urethral injury – that may turn an incomplete tear into a complete one. If there is an anterior tear of the urethra, and you are lucky enough to pass a Foley catheter into the bladder without force, leave that catheter (preferably a silicone catheter) for one month before withdrawing it carefully. Even after expert reconstructions urethral tears often cause late secondary stenosis and urinary obstruction. Inform your patient that secondary uroplastic surgery should be done if there are problems of voiding.

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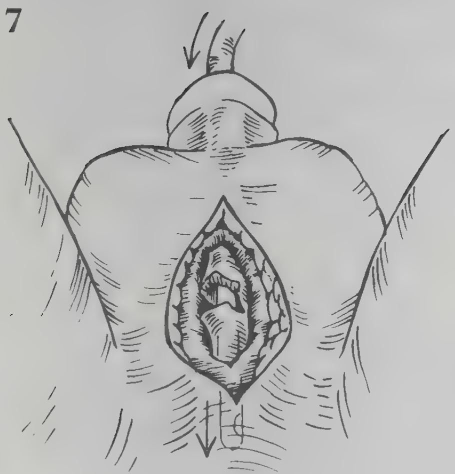
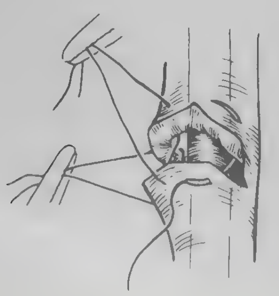
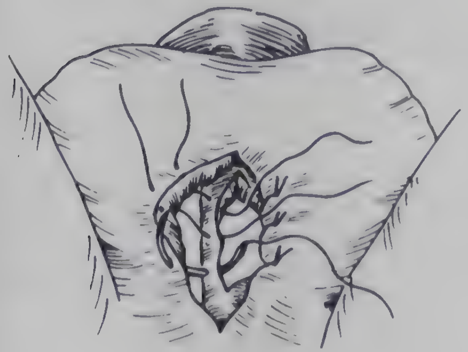




Anterior injury – delayed primary surgery: If the urethral catheter cannot be passed, and you suspect only a minor/partial tear of the urethra, insert a suprapubic catheter (small extraperitoneal midline incision, local or ketamine anesthesia). Clamp the suprapubic catheter at intervals. Voiding may be possible when the local edema and hematoma decrease. If the stenosis persists and urine cannot be passed one week after the injury, exploration is indicated.

7 **Anterior injury – primary repair:** The urethra is exposed through a perineal midline incision and sharp dissection through the spongious body of penis. Insert a urethral catheter up to the level of injury to identify the urethra during the dissection. Carefully mobilize the urethra proximal and distal to the injury, and guide the catheter into the posterior part of the urethra and into the bladder. If you succeed in passing the catheter, close the urethral wound with a few interrupted sutures (absorbable 4-0). Debride and close the skin incision. **Note:** Wounds of the penis, scrotum and external female organs may be closed by primary suture or grafting due to the copious blood circulation (p. 442).



8 Marsupialization – a controlled urinary fistula: If you do not succeed in passing the catheter, make a urinary fistula by suturing the skin edges to the urethral wound edges with a few interrupted sutures. The procedure is technically simple, and should be the standard procedure for management of urethral injuries for inexperienced surgeons. Also in injuries late for surgery, marsupialization is the safest alternative. Reconstructive surgery can be done after 3-6 months.

9 Posterior urethral injury: Do not try to suture the posterior urethra. Try to pass a catheter by the "railroad-technique" to establish a continuous urinary tract. If that is not possible due to bleeding or retroperitoneal hematoma formation, arrange for suprapubic bladder decompression and dependent drains from the retroperitoneal compartments outside the bladder.

The railroad-technique: low abdominal midline incision and exploratory incisions into the bladder and extraperitoneal anterior to the bladder (ill. 5). A small-caliber Foley catheter is passed through the urethra into the tear. The tip of the catheter is picked up by the surgeon and brought into the operating field. Another and larger Foley catheter is inserted from inside the bladder down the urethra into the tear, picked up by the surgeon and likewise pulled into the operating field. The tip of the larger catheter is cut and the small one is inserted into the larger one; let one suture secure the catheter "anastomosis". Pull the distal catheter into the bladder and inflate the balloon. Supplement with suprapubic bladder catheter and large-bore retroperitoneal drains. The urethral catheter is left for one month, then carefully removed. Do not remove the suprapubic catheter: Clamp it at intervals and see if the patient can void the bladder.

Complications of injury and surgery

Clotting of the urinary catheters

This is a persistent problem during the first 48 hours after surgery. Prevent catheter obstruction by high intake of fluid/high volumes of urine, and repeated flushing through the bladder catheters with normal saline (sterile procedures!).

Continuous hematuria

Coagulation system failure in multi-organ injured: p. 593.

- Exclude coagulation system failure and diseases that may cause hematuria (tuberculosis, schistosomiasis).
- Poor suture of the bladder wound/incision: A minor vessel in the bladder wall was not controlled by the primary bladder suture. Re-explore the bladder.
- A missed bladder injury: Do cystography/urography. Re-explore the bladder.
- A missed injury to the upper urinary tract: Do urography. Consider re-laparotomy.

Persistent pelvic bleeding

Fresh whole blood transfusion: p. 268.

The common bleeding source is torn veins of the vascular network lining the pelvic cavity (p. 469). Check the platelet count; consider transfusion of fresh whole blood. Normally the bleeding stops spontaneously when the pressure inside the pelvic hematoma has reached a certain level. If the circulation cannot be stabilized, do urgent laparotomy. Do not enter a pelvic hematoma unless it is obviously expanding: See Emergency management, p. 434.

Leaking of urine

Urine may leak out through the dependent drains or along the suprapubic catheter. The bladder and urethra heal rapidly while urine leaking normally stops spontaneously within one week. Persistent or increasing leaking indicates a missed bladder tear or urethral obstruction: Exploration should be done.

Stricture of the urethra

This may develop months after the injury. The patient can pass urine, but with difficulty. X-ray cystography will probably identify a stricture of the posterior part of the urethra. Increasing obstruction indicates use of suprapubic catheter to prevent secondary bladder failure. Refer for reconstructive surgery 3-6 months after the injury.

Total rupture of the urethra

The patient is not able to pass any urine when the urethra catheter is removed. Do marsupialization (anterior injury) or suprapubic bladder decompression (silicone catheter). Refer for reconstructive surgery.

Urinary bladder contracture

Bladder complications to spinal injury: p. 318.

It is a tragic and common complication: The patient is left with indwelling bladder catheters for more than 3-4 weeks – but the catheters are not clamped at intervals. Gradually the bladder will shrink and become contracted: The damage is done, and it is permanent The management is preventive: For one week after the injury both bladder catheters should be clamped – and opened only when the patient asks to pass urine.

Points to note – Chapter 34

The local blood circulation is excellent: Try to repair even severe injuries with primary suture.

34 Injury to the male organs

Surgical anatomy

One out of three mine-injured cases has injury to the male organs. Still the diagnosis is often missed because all attention concentrates on the extensive injuries to the lower limbs.

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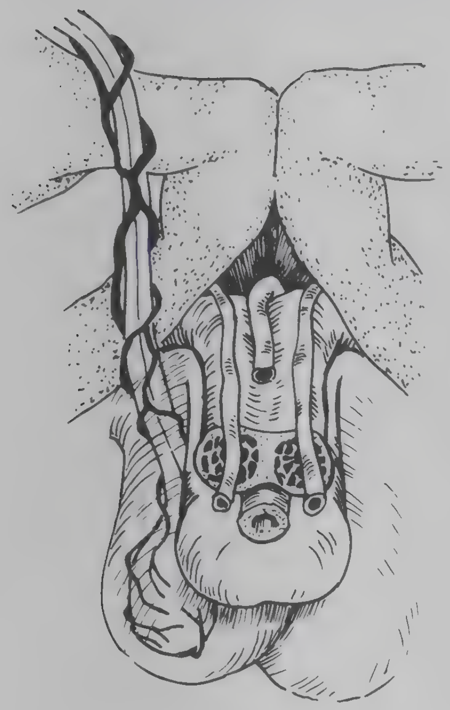
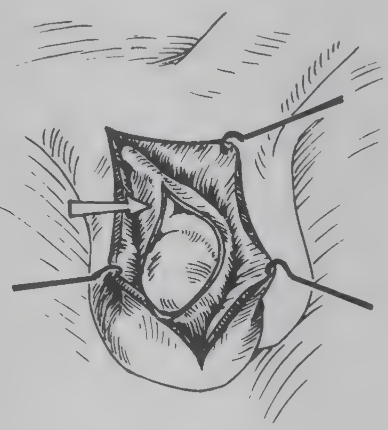


1 The structure of the penis: The penis consists of two lateral blood-filled bodies, and one central spongious body carrying the urethra. Note the central vein with one main artery on each side. Inside the scrotum the testicular artery runs close to the testicular duct; there is seldom a torn duct without the testicular artery also being damaged. The scrotal veins form a network around the duct and artery. As the blood circulation of the penis and scrotum is copious, most injuries should be managed with moderate debridement and primary closure of the wound.

2


2 The structure of the scrotum: The testicular pocket consists of a multi-layer capsule. Large amounts of blood or urine may collect inside this pocket (p. 433). Collections of fluid inside the scrotum always resorb spontaneously.

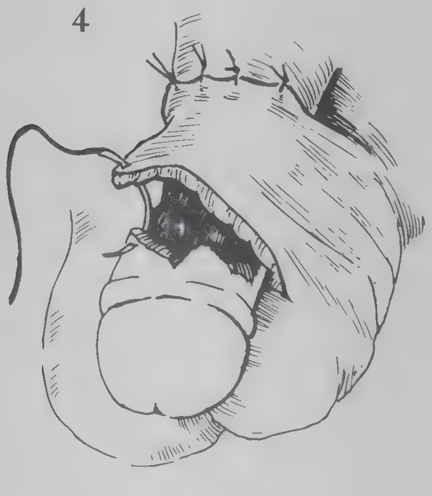
Injury to the penis

Injury to the urethra: p. 436.

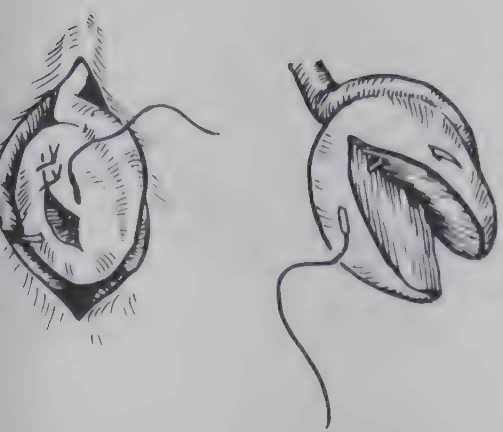
The main point is whether there is urethral injury or not: Look for blood in the urethral opening; carefully pass a bladder catheter. Leave the urethral catheter until the soft tissue edema is gone. The wounds of the soft tissues are debrided and closed with primary suture over a small soft rubber drain.

3


3 Injury of penis – skin graft for primary closure: Injuries with loss of tissue are managed by free split-thickness skin grafting. Meshed grafts may cover even extensive wounds. Note the indwelling catheter.

4


4 Extensive injury – flap graft: To cover deep wounds, flaps are mobilized from the abundant scrotal skin.



Injury to the scrotum and testis

Closed injuries of scrotum may leave a formidable scrotal hematoma, but in most cases the testicles escape damage. A swollen and very painful testicle should be explored and tears repaired, otherwise most closed injuries may be observed without exploration. In all penetrating injuries the testis should be explored.

5 Debridement of the testis: The wound is debrided and extended, the capsule around the testicle is incised, and the testicle delivered into the wound. Small tears of the testis are sutured. Major tears are debrided with wedge-resection and closed with interrupted sutures. The capsule and skin are closed over soft rubber drain.

6

6 Extensive scrotal injury – try to save his testis: Manage the testicular injury. Then make an incision into the thigh and form a subcutaneous thigh pocket for his testis by blunt dissection. Mobilize the spermatic cord and the testicle by proximal extension of the wound. Tunnel a subcutaneous canal for the cord into the thigh pocket, and put the testicle into the pocket. Close the incision and the wound over soft drains. As an alternative, you may transpose the testicle to the other half of the scrotum.

Massive testicular injury: The testicle will not be productive for fertilization – remove it to prevent local infection.

Points to note – Chapter 35

Study the anatomy
- note the close relationship between the uterus, bladder and rectum: p. 447. Combined injuries are common; it is a serious mistake to miss a rectal injury: p. 468
- note how the spaces and compartments of the pelvic cavity can be drained – through the vagina: p. 447. Through the perineum: p. 387. Or through a laparotomy: p. 454

The emergency surgery on non-pregnant females is simple
- make a low midline laparotomy: p. 360
- pack the bleeding wounds and the pelvic cavity with gauze: p. 365
- do not enter a retroperitoneal hematoma: p. 468

Basic life support to the pregnant woman must not be delayed: p. 449

Basic life-saving surgery to the pregnant woman consists of
- **Section**
  - know the exact reasons to do emergency section: p. 450
  - train to do section guided by experienced staff: p. 452
  - note that section may also be done under local infiltration anesthesia: p. 672
- **Management of missed abortion**
  - know the clinical signs: p. 450
  - know when and how to start spontaneous delivery: p. 451

- **The objective of emergency surgery is to save the mother; but in some cases you may have to sacrifice the fetus**

35 Injury to the female organs

Surgical anatomy and physiology

Except during late pregnancy, isolated injuries to the female organs are uncommon. The anatomy of the pelvic cavity is complex – associated injuries of the vascular, and tears of the colon, rectum and bladder are the main problems.

The main sources of bleeding

- The iliac vessels: Control initially by compression of the distal aorta. Do not hesitate to ligate one internal iliac artery. Consider ligature of one external iliac artery in young patients.
- The pelvic venous network (p. 469): Do not enter a retroperitoneal hematoma; normally the bleeding stops spontaneously when the pressure inside the hematoma increases. Bleeding to the abdominal cavity: Control by gauze packing. Especially in the pregnant patient the pelvic veins are dilated and bleed heavily when torn.
- The ovarian and uterine arteries are common sources of retroperitoneal hematomas. The collaterals are many; the arteries may be ligated to control bleeding.
- Separation of the placenta may cause severe uterine bleeding. The management is urgent operative delivery.

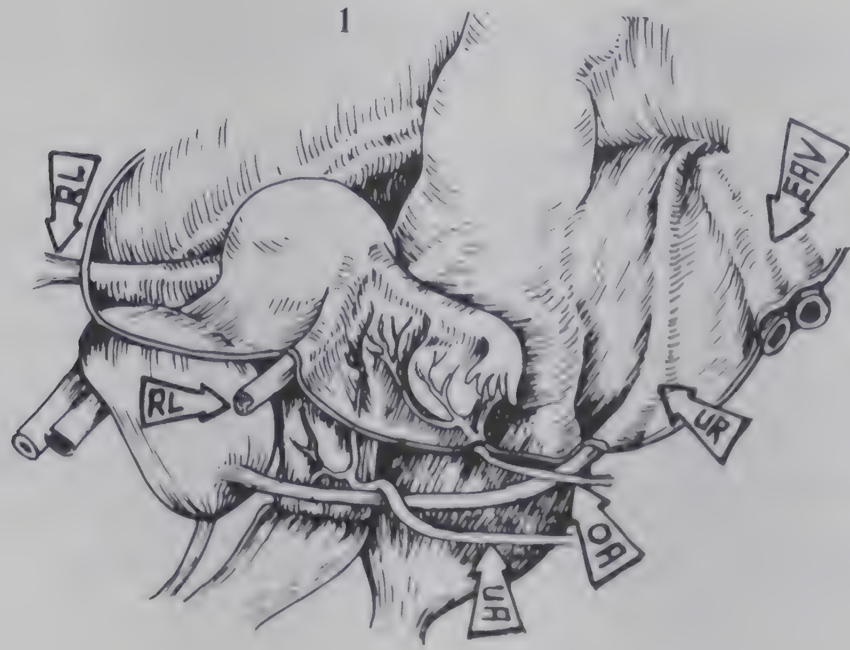
The main sources of infection

- Wounds of the colon and rectum may cause abdominal and retroperitoneal abscesses: Establishing a diversion stoma and effective drainage have first priority. Repair of the female organs can be done during the second-look laparotomy.
- Vaginal tears may infect the retroperitoneal space: Drain the retroperitoneal space through the vaginal wound.
- Associated bladder injuries are common: Drain the retroperitoneal space and decompress the bladder (suprapubic catheter) to prevent urine phlegmon, and urine fistula to the rectum or vagina.

Injury to the pregnant woman

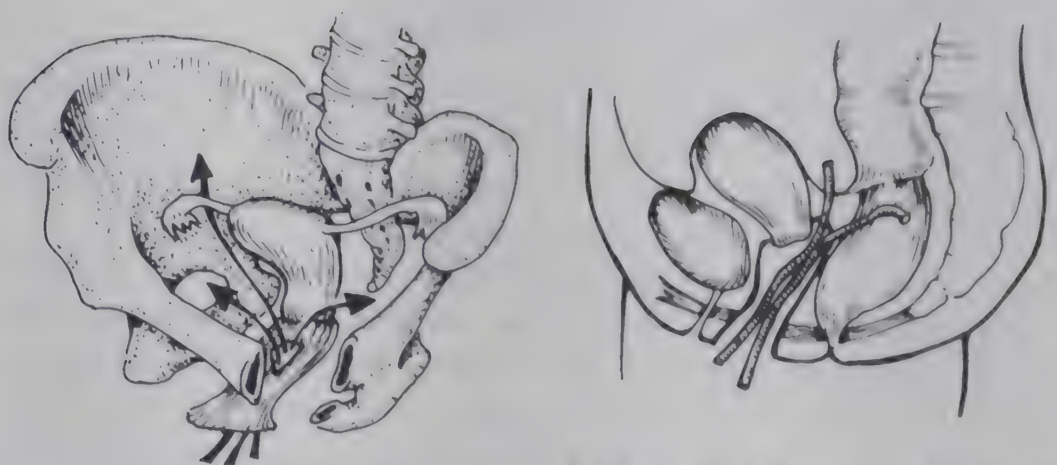
- Concentrate on the mother. Also the life of the fetus depends on early basic life support to the mother.
- During pregnancy the physiology is changed: Airway management (risk of aspiration) and early volume therapy (risk of fetal hypoxia) are essential.

1



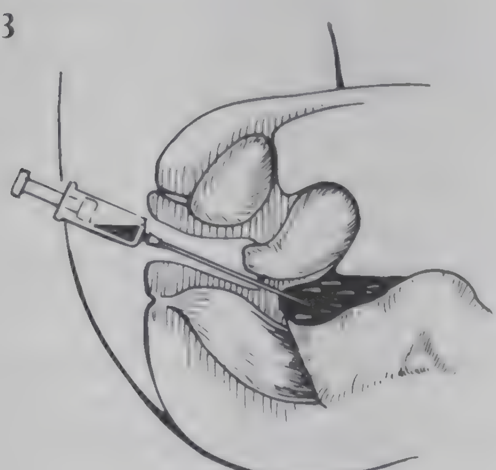
1 The non-pregnant woman – relationship to important pelvic structures: Note the uterine artery (UA) "riding" on the ureter (UR) just lateral to the uterus. In this area the ureter may be damaged during uterine surgery unless you work close to the uterus. The uterine artery is a branch of the internal iliac artery; it is a main source of pelvic hematomas and may bleed briskly. You may control the iliac vessels distal to the sigmoid mesentery. Note the close relation between the external iliac artery and vein (EAV) and the pelvic organs. The ovarian (OA) and uterine arteries carry the blood supply to the ovary, tube and uterus. The arteries anastomose inside the broad ligament between the uterus and the pelvic wall (ill. 10). The two round ligaments (RL) between the uterus and the anterior abdominal wall carry no major blood vessels.

2



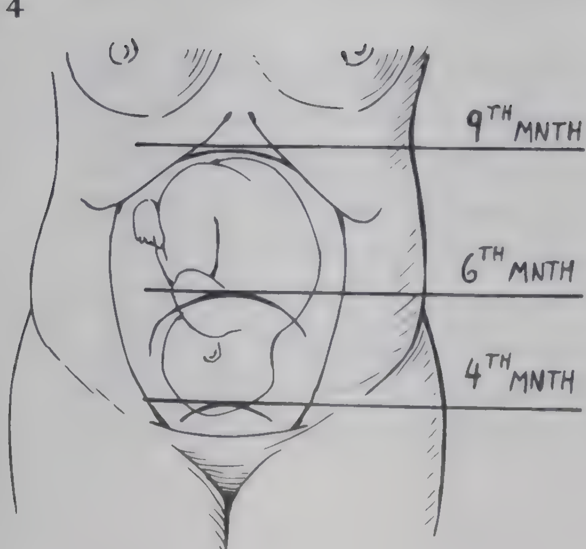
2 Pelvic infection and drainage: Infection may ascend into the retroperitoneal pelvic space through vaginal tears. (The pelvic bone is shown cut for reasons of illustration.) Do not close a vaginal tear – use it for dependent drainage by large-bore soft tubes. Also in cases without vaginal injury, the vagina may be used to drain both the retroperitoneal compartments and the abdominal cavity.

3



3 Exploratory puncture of the rectovaginal pouch: By manual examination through the vagina and rectum you can identify hematoma and abscess formation in the pouch between the uterus and rectum. Collection of fluid is confirmed by puncture with a long wide-bore needle in the midline just behind the uterus (local anesthesia of the vaginal wall). Aspiration of blood indicates laparotomy.

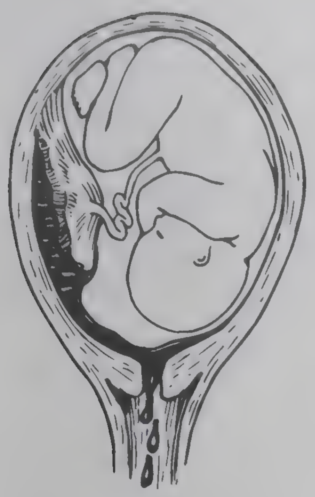
4



4 The pregnant uterus: After three months of pregnancy, the uterus rises above the pelvic bone. From the 3rd-6th month the uterus contains much amniotic fluid which provides a certain protection of the fetus from blunt injuries. During the last third of pregnancy the uterus is of formidable size, and

most penetrating abdominal injuries will also hit the uterus. During the end of pregnancy, the wall of uterus is thin: It may rupture after blunt injuries.

5



5 **Placental separation after injury:** The placenta carries the blood supply to the fetus. Even moderate blunt injuries can separate the placenta from the uterine wall. Normally, but not always, there is vaginal bleeding after placental separation. Also the separation may be gradual, and the clinical signs develop 48 hours after the injury. The fetus may survive a moderate separation, while a major separation is fatal to the fetus. Due to the blood loss placental separation may even be fatal to the mother unless operative delivery is done early. During the first three months of pregnancy spontaneous abortion follows placental injury and fetal death. Fetal death late in pregnancy normally provokes spontaneous labour and delivery within two days after injury.

Physiological changes during pregnancy increase the risk of complications of injury

- **Increased local bleeding:** There is an increase in the blood circulation of the vascular network inside and around the female organs. The pelvic veins are dilated and carry much blood. Even low-energy injuries and fractures may cause severe blood loss and hematoma formation.
- **Changes in the general circulation:** During pregnancy the blood volume of the mother is increased by 30-50%, the cardiac output is increased, the pulse rate is increased, and the blood pressure is slightly decreased. Late in pregnancy, the uterus with the fetus compresses the caval vein: The venous return to the heart is reduced – especially in the supine position (the cava syndrome). Altogether the mother may lose 1000-1500 ml of blood, and still carry few clinical signs of hypovolemia.

The normal response to blood loss: p. 107.

- **Note that the pregnant uterus is not a vital organ – monitor the fetal heart rate:** Also the pregnant woman's first response to hypovolemia is central shunting of the blood circulation to supply the vital internal organs. The blood supply to the limbs – and also to the uterus and the fetus – is reduced. Due to the cava syndrome, the decrease in uterine and fetal blood supply may be a very early response to bleeding.
- **The fetus responds to hypoxia with low heart rate:** The normal fetal heart rate is 110-150/minute. A heart rate of 100-110 is slight bradycardia. A fetal heart rate below 100 is considered as grave bradycardia and indicates fetal hypoxia.
- **Fetal hypoglycemia:** The fetus drains the glucose and glucogen depots of the mother. Especially during the last months of pregnancy frequent and high intake of carbohydrate is necessary to prevent fetal hypoglycemia. In areas where starvation is common and the evacuations protracted, hypoglycemia after injury is an important risk factor for both mother and fetus.
- **Thrombus complications:** There are alterations of the coagulation system during pregnancy, and the result is increased risk of thrombus formation after surgery. And there is an increased risk of coagulation system failure (DIC) secondary to uterine injury. DIC during pregnancy does not respond to heparin therapy.

Coagulation system failure: p. 593.

Anesthesia to the pregnant woman

Take special precautions for the pregnant patient:

- Airway support: The stomach empties slowly and aspiration of stomach content into the esophagus is common late in the pregnancy. Insert naso-gastric tube and empty the stomach before evacuation starts. Consider endotracheal intubation during surgery.
- Respiratory support: Late in the pregnancy as the uterus compresses the lungs, the respiratory capacity is decreased. Even moderate lung injuries may cause fetal hypoxia. Also a minor hemo-pneumothorax should be drained. Give oxygen if available.

Late in the pregnancy the respiratory rate is normally increased.

- Support the circulation: Place the mother in left supine position to avoid compression of the caval vein by the uterus.
- Volume pre-load before anesthesia: The hypovolemia may be hidden, and the blood loss greater than indicated by standard clinical signs. Give flush infusion of 1000 ml Ringer as a routine.
- Spinal anesthesia – even after volume pre-load – may cause sudden circulatory collapse and fetal death in unstable cases.
- Blood-type and prepare for autotransfusion: There is an increased tendency of bleeding during surgery, especially inside the pelvic cavity. Expect considerable blood loss during laparotomies late in the pregnancy.
- Monitor the fetal heart rate continuously before, during and after surgery: Fetal bradycardia (heart rate below 110/minute) is the most common sign of fetal distress. Also fetal tachycardia (heart rate above 160-170/minute) may be seen.
- Consider glucose infusion before and during the surgery: Fetal bradycardia may not only indicate hypoxia. A combination of hypoxemia and hypoglycemia is common.

Most pre-term babies have low blood glucose at delivery. Enteral or i.v. glucose: p. 153.

- High doses of analgesics and diazepam may hurt the fetus: The drugs pass into the placenta and enter the fetal blood circulation. In high doses they depress the oxygenation of the fetus.
- Mental support to the mother is the best tranquilizer: Her main concern is for the unborn child. Let one relative be with her. Inform her that you are concentrating on the life support for the mother in order to save the child.

Injury to the pregnant woman

First priority: Prevent hypoxemia of the mother by very early basic life support

Even five minutes of grave fetal hypoxia may cause permanent damage to the fetus. The objective is thus not to re-establish respiration or to re-establish the uterine blood perfusion. The objective is to prevent airway obstruction and circulatory shock.

Surgical delivery is life saving if done early
Urgent surgical delivery saves the child if it is done within minutes. There is no time for wait-and-see! The indications are
- Pregnancy during the 8th and 9th month.
- Fetal heart rate below 100, or above 160-170
- or ongoing bleeding from the uterine cervix
- or the mother is in circulatory shock that does not immediately respond to volume therapy.

Separation of the placenta
It is the most common threat to the fetus. A major separation may also be fatal to the mother. The clinical signs may develop gradually and late. Monitor for 48 hours after the injury the clinical signs of separation:
- Blunt or missile injury.
- The uterus is contracted and very sensitive (hard and painful on palpation).
- Vaginal bleeding is common. Note that the degree of bleeding is not indicative. Though the bleeding may be slight or absent, the separation may still be considerable.
- Fetal distress: Do not wait for signs of fetal distress to develop. Fetal bradycardia is a late sign of placental separation; it indicates that the life of the fetus is in danger: Do immediate surgical delivery.

Fetal death
In nine out of ten cases the dead fetus is delivered spontaneously within two weeks. Parts of the fetal or placental tissues retained inside the uterus may cause uterine infection and coagulation system failure.
- Early abortion: During the first three months of pregnancy, curettage should be done as a routine after the delivery (ill. 6).
- Late abortion: From 15 weeks of pregnancy curettage carries a high risk of uterine bleeding and perforation. Give i.v. oxytocin 10 IU in repeated injections. Delay the curettage until most of the placental tissues are delivered spontaneously.
- Missed abortion before the 7th month of pregnancy: The dead fetus is not delivered spontaneously, but there may be few clinical signs. The diagnosis should be done carefully. Examine the mother at intervals for six weeks. If the fetal heart rate cannot be identified and the uterus does not increase in size, there is a missed abortion: Start the delivery (see below) and do curettage unless there are signs of infection.
- Missed abortion with infection carries a high risk of septicemia and severe bleeding. Give broad-spectrum antibiotics and metronidazole. Delay the delivery (terbutaline-glucose infusion stops the uterine contractions) and the curettage until the infection recedes.

The management of septicemia: p. 644.

- Fetal death after the 7th month of pregnancy: There is a high risk of severe spontaneous bleeding if the fetus is retained more than two weeks inside the uterus. Start delivery immediately when the diagnosis is confirmed.

Procedures to start spontaneous delivery

- Mix oxytocin 10 IU in 1000 ml glucose 50 mg/ml infusion. Start infusion rate: 5 ml/hour. Increase the infusion rate stepwise until effective. Maximum dose: 120 ml/hour.
- Dilate the cervical canal with the fingers to stimulate uterine contractions.

The dying mother late in the pregnancy

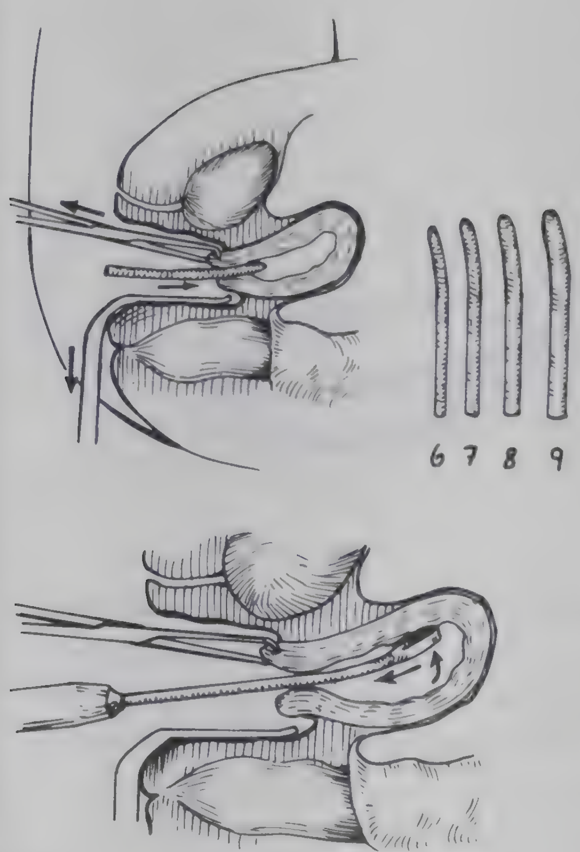
Emergency laparotomy: p. 155.

The reason for early death after injury is severe bleeding. Forward emergency laparotomy may save the life of both mother and child and should be done on ready indications. But in the obviously dying mother there may be exceptions to the standard procedure: Do not waste time on aortic compression before the laparotomy is done. At least try to save the child: Do the midline laparotomy directly. Ignore the abdominal bleeding – split the uterus, deliver and start basic life support on the fetus. If done within 10 minutes after the circulatory collapse, surgical delivery may save the child.

Blunt and blast injury

It may cause placental separation, even if the injury is low-energy. Unless there is indication for surgical delivery, the management is volume therapy, oxygen and bed-rest with close monitoring of the fetal heart rate. Late in the pregnancy the uterine wall is thin and may rupture. Suspect uterine rupture if you palpate fetal limbs outside the uterus. The management is urgent surgical delivery and repair of the uterine tear. Normally the bleeding is moderate.

6



6 Uterine curettage: The uterine mucosa including all necrotic fetal remnants are removed. Curettage is done under low-dose ketamine anesthesia. The uterus is pulled downwards by clamping the superior lip of cervix while an assistant retracts the posterior vaginal wall. The cervical canal into the uterine cavity is dilated stepwise by gently inserting Hegar steel dilators from size 6 mm until 8 or 9 mm. The curet is inserted through the dilated cervical canal, and the uterine mucosa and fetal remnants are removed from every part of the uterine cavity. Even small amounts of necrotic tissues left may cause serious infection. After the curettage, the uterus will contract and bleeding will recede. Gauze tampons are left inside the vagina for 12 hours. Major uterine bleeding is managed by inj. oxytocin 10 IU i.v and tranexamic acid (Cyclokapron) 0.5-1 g i.v. **Notice:** Curet carefully, do not penetrate the uterine wall. Minor penetrations heal spontaneously covered by antibiotics. Explore by laparotomy if you suspect abdominal bleeding or intestinal injury.

Penetrating injury

Shrapnel from antipersonnel mines is the most common cause of wartime injury to the female organs. The dramatic lower limb injuries normally dominate the picture, and the internal injury is often missed: Always suspect internal pelvic bleeding in mine cases in circulatory shock. Even tiny shrapnel may penetrate the pelvic diaphragm and cause extensive internal pelvic injury. A low midline incision is the standard incision for exploration of the internal female organs. Consider two-step surgery in major and multi-organ injuries:

Two-step emergency laparotomy: p. 133.

Concentrate on fetal support, bleeding control and drainage at the time of injury. Delay the repair and reconstructions of the female organs until a second-look laparotomy after 24-72 hours.

- Associated injuries: Unless the fetal state is critical, close all intestinal wounds, do diversion enterostomy and wash out the abdomen with normal saline before you enter the female organs and the pelvic retroperitoneal space.
- Minor tears of the uterus without fetal or placental damage are debrided and closed by two-layer suture (ill. 8).
- Major uterine damage: The fetus is delivered and the uterine tears debrided and closed. If the vital signs of the mother are poor, control bleeding by artery ligatures and gauze packing. Delay the uterus amputation until the second-look laparotomy.
- Extensive perineal or vaginal soft tissue injury: Secondary wound infection with sepsis is a risk for both mother and fetus. A temporary diversion sigmoidostomy helps avoid fecal contamination.

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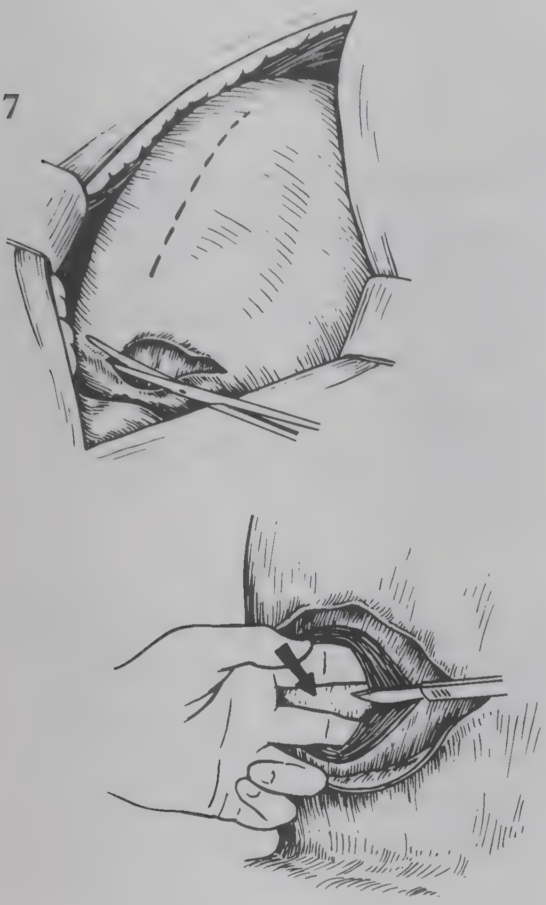
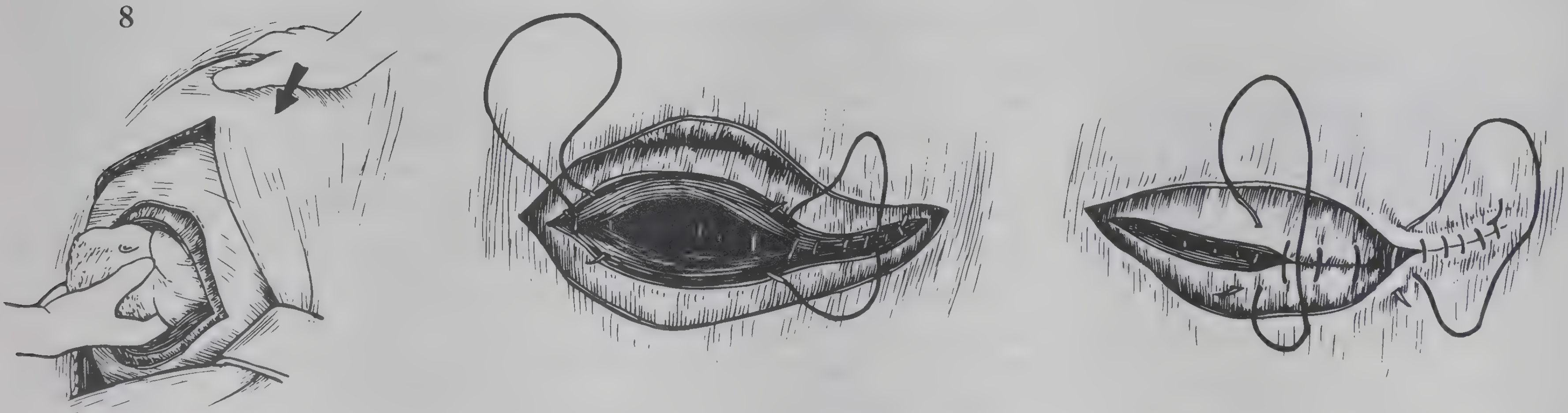


7 Surgical delivery of the fetus: The uterus is exposed through a low midline incision. (For reasons of illustration the incision shown is more extensive than standard.) You may extend an uterine tear for access to the uterine cavity. Or close the tear and use a standard transverse or longitudinal (dotted line) incision through the frontal uterine wall. In this case, a low transverse incision is done just above the bladder. The peritoneum is incised and the bladder peritoneum is swept downwards by blunt dissection. The uterine muscular wall is incised carefully – the head of the fetus is just underneath the wall (arrow). Once the uterine cavity is reached, continue the incision with fingers inside the uterine cavity to protect the fetus.

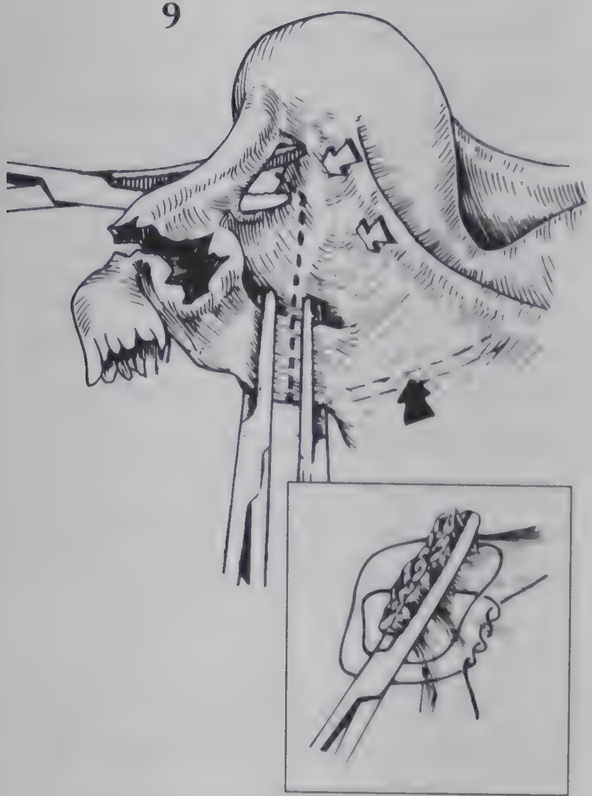
8



8 The delivery: The head of fetus is delivered, and the rest of the body under manual compression at the top of the uterus. Start immediately basic life support to the fetus. Give i.v. oxytocin 10 IU to the mother, and mobilize the placenta from the uterine wall under slight traction and very careful blunt dissection. Clean the uterine cavity of blood clots, count the gauze pads, and close the uterine incision by two-layer continuous muscular suture and separate suture of the peritoneum.

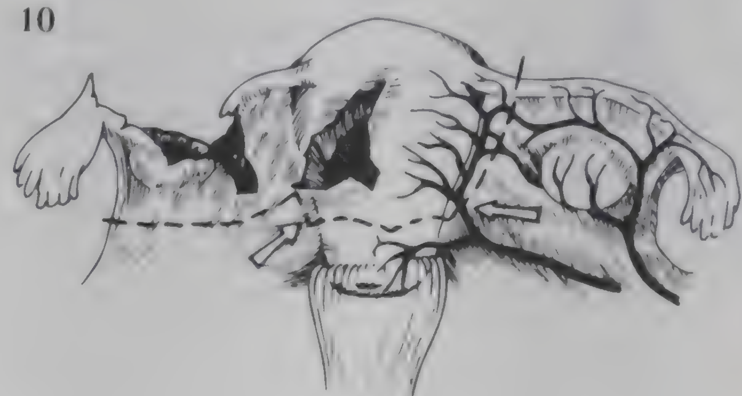
Injury to the non-pregnant woman

9



9 Resection of ovary and tube: The blood supply to the female organs is generally rich. Minor injuries are managed by limited debridements or partial resections. The ovaries produce female sex hormones and should be saved unless extensively damaged. Major injuries to the tube and ovary are managed by resection: The resection is done through the peritoneal sheet lateral to the uterus (the broad uterine ligament) midway between the tube and the round ligament (dotted line). The ovarian artery is located lateral in the ligament. It is divided between two clamps and ligated by a ligating stitch as illustrated. The medial part of the broad ligament carries few vessels; it is divided stepwise and ligated. The tube is clamped, cut and ligated close to the uterine corner. The white arrows indicate the vascular network close to the lateral uterine wall (ill. 10). They may bleed briskly during deep dissections close to the uterus. The black arrow indicates the localization of the ureter beneath the broad ligament: During all pelvic surgery, keep the localization of the ureters in mind.

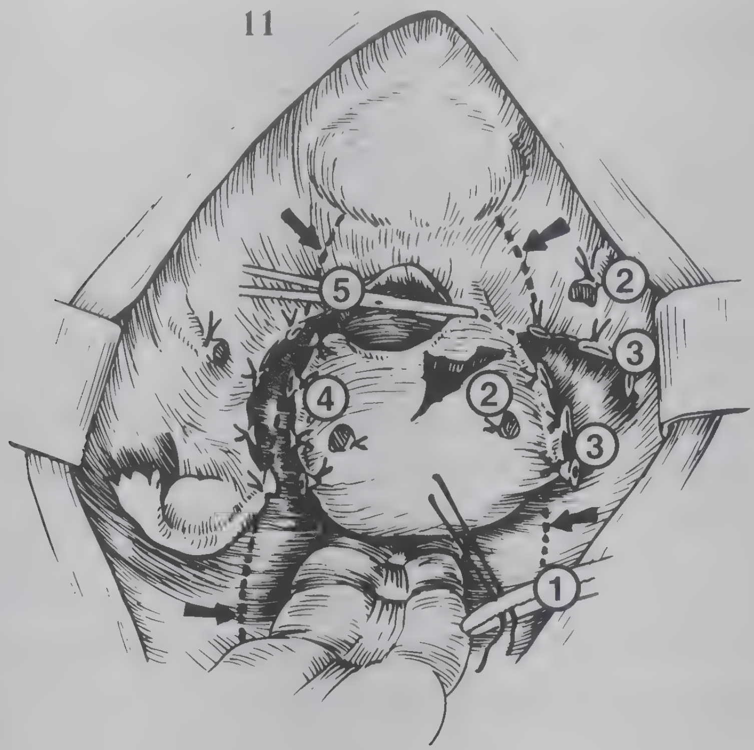
10



10 Major resections due to extensive injury: There are no rigid rules whether reconstruction or resection should be done – assess each injury carefully. Attempts to reconstruct and close extensive injuries at the time of primary surgery carry increased risk of wound infection. Most probably tube stenosis will follow the attempt to reconstruct a torn tube. And the uterus here illustrated cannot carry a fetus after debridement and repair. But if you are in doubt, apply a conservative strategy at the time of injury: Complete the debridement, control bleeding and drain the injury during the primary surgery. Decide whether to repair or do resection at a second-look laparotomy.

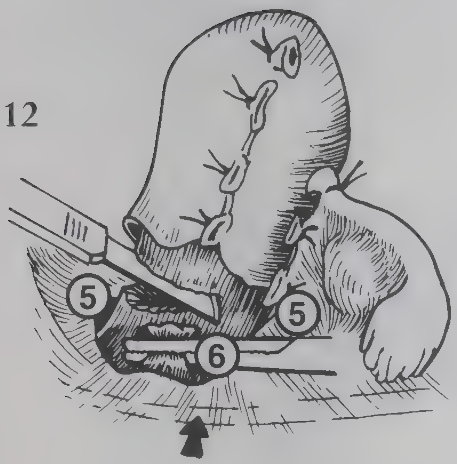
The standard line for resection of ovary, tube and supravaginal amputation of the uterus is shown (dotted line). Note the two main branches of the uterine artery: The proximal branch (arrow) is cut and ligated during uterus amputation; the distal branch is left to supply the uterus stump after amputation. Also note the vascular network along the lateral wall of uterus: Do not carry the dissection too close to the uterus as that will increase bleeding.

11



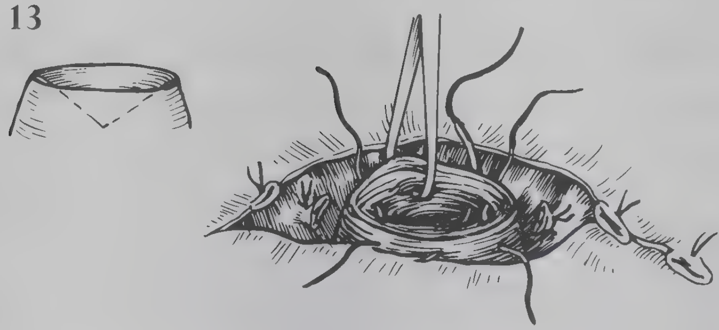
11 Supravaginal amputation of the uterus. Step one – mobilization of the uterus: Keep the ureters in mind (black arrows). (1) Insert stay sutures at the top of uterus to pull the uterus into the operating field. (2) The round uterine ligament in front of the tube (ill. 1) is cut between clamps and tied. (3) The tubes and the broad ligament are cut stepwise between clamps and tied (ill. 9). (4) Split the broad ligament between clamps along the lateral uterine wall. Proceed stepwise and do not include too much tissue inside each clamp, or else the ligatures may slip.

12



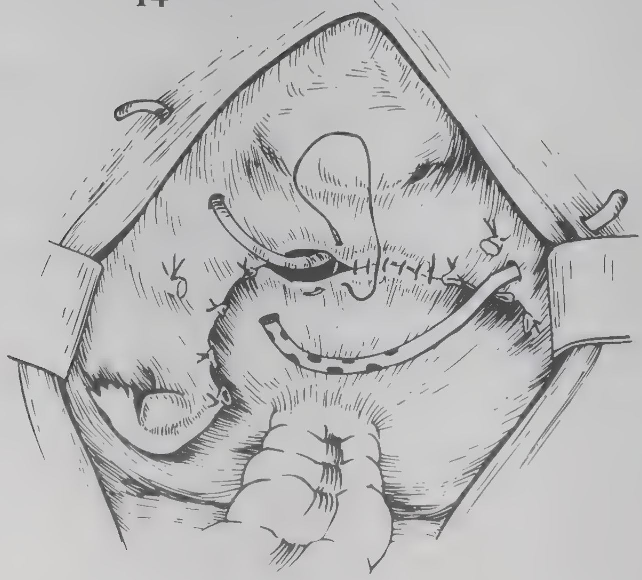
12 Step two – control the uterine artery (white arrow) before the amputation is done. Careless dissection and clamping of the artery may damage the ureter (black arrow). (5) First split the peritoneum anterior and posterior to the uterus (also see p. 365). Wipe the peritoneum downwards by blunt dissection. (6) Identify the uterine artery immediately under the peritoneum, clamp the proximal branch of the artery close to the uterine wall, tie the artery well. Then decide the level of amputation (palpate the top of the vagina).

13



13 Step three – the amputation: The neck of uterus is cut sharply in a conical fashion. Bleeding is moderate if the uterine artery is properly tied. The uterine stump is closed by interrupted cross sutures (absorbable 2-0). Note the ligatures on the uterine artery.

14



14 Step four – dependent drainage: The peritoneum is closed over the uterus stump by continuous suture. Drain both the retroperitoneal space at the top of the uterus, and the abdominal cavity by separate large-bore soft tube drains with multiple side holes. The drains are inserted through separate stab incisions close to the groin.

Complications of injury and surgery

Management of pelvic abscess formation: p. 479.

Rebleeding and abscess formation

A common source of uncontrolled bleeding after surgery is a poorly tied uterine artery. The artery may bleed briskly. Puncture of the rectovaginal pouch and aspiration of blood are diagnostic. Urgent reoperation is necessary. A minor hematoma at the top of the amputated uterus is common. Major retroperitoneal hematoma or abscess formation is indication for secondary laparotomy.

Mental depression secondary to surgery

Depressive post-operative mental reactions are common in fertile females; especially after uterus amputations the reactions may be severe. Early mental support to patient and her family is preventive. Explain the nature of the surgery, which sexual function is lost and which is preserved.

Sexual dysfunction

Uterine injuries may end up with strictures and scarring, causing spontaneous abortions. Tube injuries and adhesions after pelvic infections may cause permanent infertility. Hormonal supportive therapy is necessary after resection of both ovaries.

Points to note – Chapter 36

There are no special points to note; all medical staff involved in patient care should study the chapter carefully.

36 Complications of abdominal surgery

Post-operative monitoring

The organization

Quality control programs: p. 697.

The post-operative monitoring and rehabilitation is as important as the surgery. Under high casualty load the quality of the post-operative monitoring deteriorates – unless it is strictly organized. And unless the surgeon in charge also monitors the monitoring system.

Normally the capacity for surgery is not the limiting factor, but the capacity for post-operative monitoring and rehabilitation. That is why the staff-training program is a continuous and integral part of wartime surgery. See p. 31 and 578.

The Patient Chart:p. 54.

- **One case – one responsible:** The surgeon who did the primary surgery should be the one responsible day to day for the patient. Also among the bed department staff, one paramedic is day-to-day responsible for the case. The same goes for the family if they take part in the nursing. Only in this way can complications be identified soon enough to be managed.
- **The objective:** Monitoring means continuous and exact examination of the general state, the wounds, the nutrition and the rehabilitation. In each case the surgeon doing the primary surgery should write exactly what should be monitored, and a time schedule for the rehabilitation.
- **Written documentation:** The results are written in the Patient Chart at regular intervals. Without a written chart, early and minor – but important – signs of complications cannot be identified. The chart follows the patient everywhere.
- **Beware the first week after surgery:** Most complications arise during the first week after surgery. The monitoring should be particularly intensive during this week.
- **Instruct the patient and the relatives:** Form a confident relationship with the patient. Often the patient and his relatives know better than the surgeon when complications are about to develop. Listen to their information. Instruct them carefully on a detailed list of the signs and symptoms they should watch for.

Check list for post-operative monitoring

The list is not meant to be comprehensive. It points out the basic elements of monitoring. Study Chapters 25-44, and add the specific points in monitoring of the specific organ injuries.

General state

- Pain and mental state: Continuously revise the analgesia. Beware that mental confusion also may indicate infectious complications and brain damage.
- Does the patient gain strength or lose strength? Does he gain weight or lose weight? How is the appetite? Weight loss and catabolism increase the risk of secondary organ complications. The nutrition should not only be correct from a physiological point of view – it should also be as delicious as possible.
- Is he cooperative? Serious and kind concern and human support are imperative. Inform him of your plan for rehabilitation. Make it clear that you expect his active participation in exercises and nutrition.

General unrest may be the first signs of lung failure.
In children: The inactive and silent child often has respiratory problems.

Respiration

- The respiratory rate: A rate of 35/minute (dog-like respiration) and a rate below 10/minute both indicate serious complications. Revise the analgesia. Rule out missed chest injury. Intensify the respiratory support.
- The respiratory effort: Is the respiration free, or does he use accessory muscles? Rule out airway obstruction. If he is weak or semi-comatose, clear the airways regularly by tracheal suction.

Blood circulation

- Pulse rate and systolic blood pressure: A pulse rate value higher than the systolic pressure indicates pain, fluid deficit – or bleeding.
- Skin blood circulation: Warm and dry skin is a positive sign. Cool and clammy skin indicates pain – or bleeding.
- Monitor the abdomen: Distention, swelling in the flanks or perineum indicate bleeding or hematoma formation.
- Monitor the exact blood loss through the drains.

The normal 2000 ml per day evaporation of an adult is increased up to 3000 ml in hot climate. Fever increases the evaporation.

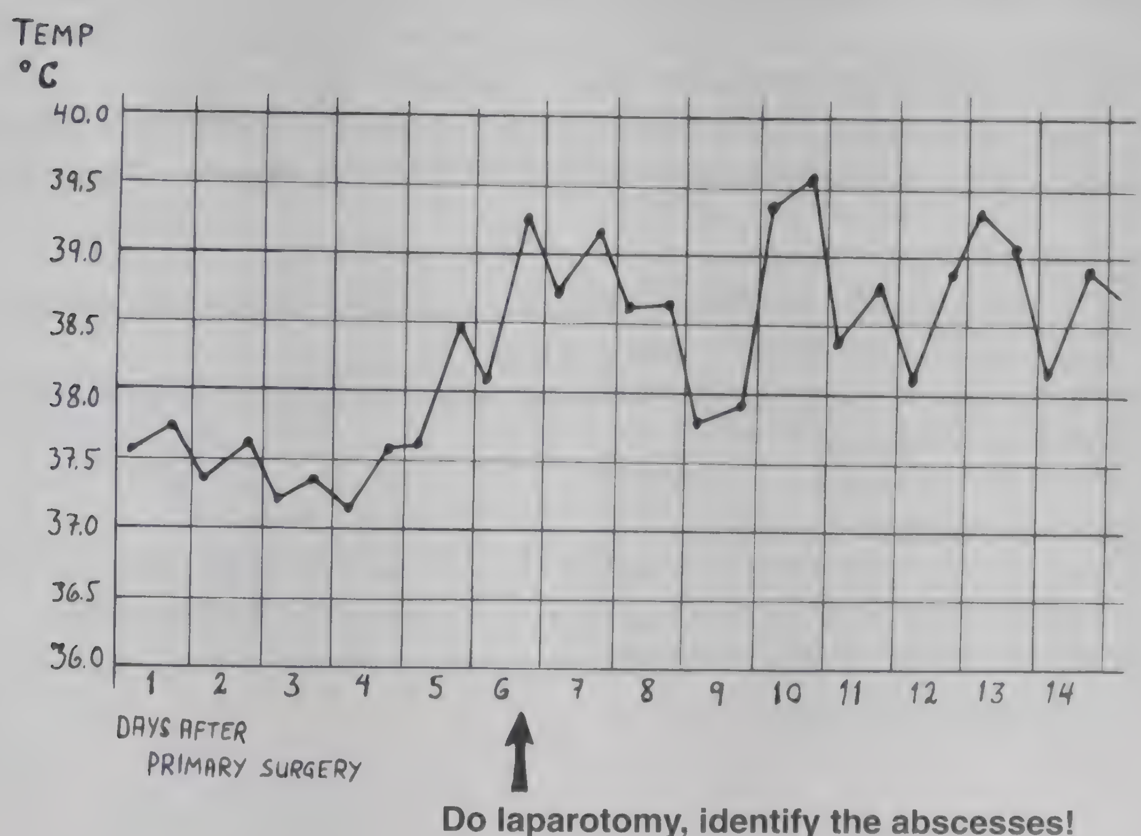
The basic daily need of potassium is 40-60 mmol. There is increased loss of potassium in abdominal injuries, add 60-80 mmol potassium daily.

The fluid balance

- The urinary output per hour (UPH): In major injuries the UPH should exceed 70 ml the first post-operative day, thereafter 50 ml. If less, he is hypovolemic or there is renal failure.
- Check the fluid-in-fluid-out balance every 12 hours, and revise the fluid program: 3000-4000 ml fluid intake is the basic daily need of an adult. Add 1000-2000 ml in all major abdominal injuries. Add for estimated blood loss. Add for estimated increased evaporation.

Body temperature

Monitor the rectal temperature. Does he have attacks of cold shivering? If so, monitor his temperature every 30 minutes to identify septicemia or abscess temperature peaks.

1


1 The abscess-temperature curve: In a patient whose state is deteriorating or does not improve, this temperature curve strongly indicates abdominal abscess formation. Typically the temperature rises 4-6 days after surgery (the most common time for intestinal wound rupture). The peaks of fever represent output of bacteria and toxins to the blood circulation.

- As a routine, continue the antibiotic regime for five days after surgery.
- Septicemia may start a chain reaction of serious complications: Start aggressive broad-spectrum antibiotic treatment without delay if you suspect septicemia.

- Re-explore the abdomen without delay. Antibiotics are no substitute for surgical evacuation of the abscesses.

The intestinal function

Expect some intestinal activity in moderate injuries within 2-3 days after surgery. Duodenal injuries and multiple injuries may paralyze the intestines for days. The signs of paralytic ileus are:
- Progressive abdominal distention
- Silent abdomen, very few bowel sounds
- Vomiting
- No gas per rectum
- Gradually less pain
- X-ray films show gas in both small and large intestine

The chest and abdomen

The examination is incomplete unless the clothes over the chest and abdomen are removed.
- Discoloration may indicate hematoma or urine phlegmon formation.
- Local swelling may indicate subcutaneous emphysema, hematoma, phlegmon or abscess formation.
- Dull percussion may indicate abscess formation or free abdominal fluid (intestinal perforation or bleeding).
- Displacement of the liver: Abscess formation under the diaphragm (the single most frequent reason for reoperation) may cause downwards displacement of the liver, increased respiratory rate and pleural effusion shown in chest X-rays.

The wounds

Leave the wounds for 4-5 days after surgery. Early manipulation increases the risk of secondary infection.
- The incision: Redness and swelling indicates infection, wound rupture or both. Remove some skin sutures and explore the incision bed-side. If there is no pus, suspect partial wound rupture: Reoperate without delay.
- Other wounds: Redness or discharge may indicate that the wound is penetrating, but the diagnosis missed initially. Debride and re-explore without delay.

The drains
- The smell: Examine both the drains and the dressings. Fecal smell indicates intestinal wound rupture or a missed injury.
- The volume of the discharge: Increasing production indicates wound rupture or fistula formation.

The enterostomy
- The circulation of the stomal mucosa: An enterostomy under tension tends to retract; the mucosa may become necrotic or separate at the skin suture.
- The production: Poor production may indicate a narrow stoma. Test with your finger inside the stoma.

Reoperate a poor enterostomy – it will not improve spontaneously.

The management of common complications

Persistent bleeding, rebleeding or hematoma formation

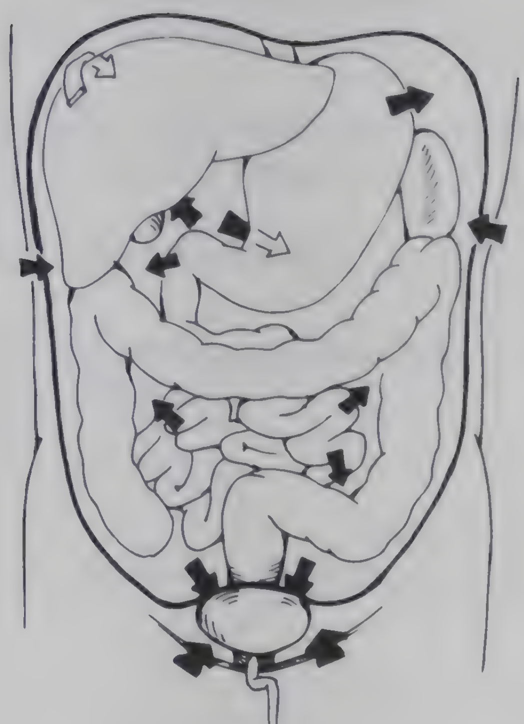
- The patient is stable or responds to volume therapy: There is no urgency, you have time enough to prepare the relaparotomy. Warm the patient to 38 degr. C – a cold patient will bleed from "everywhere" and surgery may increase the bleeding. Start transfusions with fresh whole blood rich in platelets – in patients with hemodilution surgery is a hazard. If those measures alone do not control the bleeding, prepare for surgery.
- The patient is unstable and does not respond to aggressive volume therapy: Do immediate laparotomy. Note that the circulation may collapse at the time you enter the abdomen. Consider thoracic clamping of the aorta.

The emergency laparotomy in detail: p. 155.

Peritonitis or abscess formation

Do not delay surgery: As antibiotics cannot heal the intestinal perforation, the delay makes surgery more difficult. The surgeon who did the primary surgery should do the reoperation.

2



2 **Management of abdominal abscess – step one:** Reopen the midline incision and explore the most common sites for abscess formation:

- Under the right and left diaphragm
- Between the liver and the transverse colon
- Split the gastro-colic ligament to explore "the lesser sac" behind the stomach
- Along the right and left colon, also retroperitoneally on the posterior abdominal wall
- Inside the rectovesical or rectovaginal pouch
- Retroperitoneally along the rectum/bladder inside the pelvic cavity

Step two: Wash out the abscess with warm normal saline and drain the site with double large-bore dependent tube drains.

Step three: Identify the source of abscess formation. Make sure there are no missed injuries:

- Explore the intestinal sutures and anastomosis. If the intestinal wall is necrotic, resect it leaving viable tissue. If the intestinal wall is red and swollen around a suture, better resect that part and make another anastomosis. Attempts to repair an infected suture line will probably fail. If the intestinal suture line is not that swollen, additional serosa sutures and a tag of omentum will do. **Note:** There may be more than one leaking perforation. Explore every cm of the intestine for a missed perforation.
- Abscess on the posterior abdominal wall: Mobilize the colon and duodenum close to the abscess site. The tear may be on the posterior intestinal wall.
- Explore the gall bladder, the common bile duct and the hilum of the liver: Leaking of free bile may cause local peritonitis.
- If you still cannot find the source of infection, explore the pancreas. Leaking of pancreatic juice may erode the intestines or cause retroperitoneal tissue necrosis. Mobilize the pancreas to also explore the posterior side.

Paralytic ileus

Concentrate on preventive measures:

- Get the patient out of bed the first day after surgery
- Leave the naso-gastric tube for decompression until there are bowel sounds
- Start peroral or enteral nutrition as soon as there are bowel sounds

The management of paralytic ileus consists of

- Gastric decompression. Check the position of the gastric tube
- Analgesia and sedation
- Rectal rubber tube
- Be patient: The intestinal function will improve unless there is also mechanical obstruction. If the general condition is worsening, do exploratory laparotomy before he is too weak to allow surgery

Mechanical ileus

Proximal to the site of intestinal obstruction, the intestine becomes distended, discolored and filled up with gas and fluid. Intestinal sutures may rupture; also spontaneous perforations may occur. The diagnosis is based upon clinical signs, not X-ray films. The clinical signs are

- During the first 24 hours of obstruction, colic pain will come and go at regular intervals. After 24 hours the pain will recede and the intestine then enters a state of paralysis.
- During the first 24 hours the bowel sounds are of the stenotic type, like flushing fluid from a syringe. After 24 hours the bowel sounds recede, and the abdomen becomes silent.
- If the obstruction is proximal on the small intestine, the stomach will fill with fluid and gas: The patient will vomit.
- The abdomen becomes gradually distended, with increasing "drum sound" on percussion.

> "Do not let the sun set over an obstructive ileus!"
> Reoperate before the abdomen becomes silent, before the intestine enters the paralytic stage.

Identify the site of obstruction. The most common reason is herniation of a loop of the small intestine – either through an incision of the mesentery (the surgeon "forgot" to close the mesenteric incision after resection-anastomosis), or herniation behind the intestines delivered for enterostomy (the surgeon "forgot" to close the space lateral to the enterostomy). Patients with previous infectious abdominal disease may have peritoneal adhesions, that is, tissue strings that may strangulate the small intestine. Manipulate the intestines carefully and without force. If the intestine is very distended, deflate it by needle aspiration of gas and fluids. Cut the adhesions causing the obstruction and leave the abdomen: The more you manipulate, the more adhesions tend to develop.

Massive ascariasis, amebomas and intestinal tuberculosis may also cause strangulation or stenosis of the intestine.

Rupture of the midline incision

Hematoma and/or infection in the abdominal wall is the most common reason. Also poor gastric decompression, abdominal rebleeding and ileus may cause abdominal distention and wound rupture. Any rupture – even partial – should

be explored and resutured on the operating table. Do not delay the surgery as that will increase the abdominal distention and make reconstruction difficult. Decompress the stomach by naso-gastric suction before surgery. Open the midline incision until the peritoneum and explore the rupture, as it tends to be more extensive than imagined. Evacuate the hematoma and debride necrotic tissue carefully. Search well to the sides for abscess formation. If the intestines are distended and paralytic, consider gastrostomy with tube decompression of the duodenum. Close the incision with all-in-one interrupted sutures (non-absorbable no.1 or 2) at close intervals. Tie the sutures over rubber tubes (pieces of i.v. catheter) or over a roll of gauze. **Note:** Do not close the incision under tension. Either make lateral relief incisions, or interpose split infusion bags until the intestines are decompressed, and definitive closure can be done.

Temporary abdominal closure: p. 359.

Enterostomy complications

The management depends on the source of the complication.

- The stoma is necrotic: The stoma may retract or become necrotic if the intestine is under tension. The complication is common in colostomies of the fixed parts of colon when the colon is not sufficently mobilized from the posterior abdominal wall. Open the midline incision, release the necrotic stoma and resect the necrosis. Convert a necrotic loop-stoma to a double-barreled end-stoma. Mobilize the colon well before the stoma is arranged.
- The stoma is retracted, but not necrotic: Mobilize the colon through wide peritoneal incisions. If the stoma is still under tension, arrange a distal ileostomy.
- Stenosis of the enterostomy: Extend the abdominal wall incision under local anesthesia.
- Separation or infection around the enterostomy: The reason may be poor nursing. Or hematoma or abscess formation in the abdominal wall close to the stoma, in which case you extend the stoma incision and evacuate the infection.

There are particular problems with enterostomies of the right colon: p. 385.

Ventral hernia

Permanent defects of the abdominal wall are not uncommon after abdominal injury and surgery. The reasons may be the following:

- Injury with loss of abdominal wall muscle and fascia. The temporary closure with skin grafts or skin-muscle flaps leaves defects in the wall where the peritoneum and abdominal contents may protrude under the skin.
- Unmanaged ruptures of the midline incision (due to infection or poor surgical technique) cause a gap between the two rectus muscles where the hernia protrudes.
- Necrotizing infections may necessitate excision also of the abdominal wall muscles.
- Fat patients carry an increased risk of post-operative ventral hernia. Also severe vomiting and coughing after surgery, or rough evacuations may cause ruptures of the midline incision, especially if relief sutures (p. 370) are not applied.

Necrotizing fasciitis: p. 580.

The management differs depending on the localization and size of the hernia, and the state of the patient:

- Narrow hernias with entrapment of the small intestine: Urgent surgery and repair, else obstructive ileus may develop.
- Broad-based hernias above the umbilicus: The hernias are seldom painful, and surgical repair is often unsuccessful. A broad compressive belt is the treatment of choice.
- Hernias below the umbilicus should be operated on.
- Reconstructive surgery often fail in fat patients, patients with chronic coughing or obstructive lung diseases, and in the presence of enterostomies or infected wounds.

In minor cases reconstructive surgery can be done with one of the standard hernia operations (see any textbook on Abdominal surgery). In cases with extensive defects, local rotation flaps must be mobilized to close the defects. Depending on the localization, the latissimus, upper or lower rectus or the tensor fascia lata flap may be used.

Soft tissue rotation flaps: p. 201.

Continuous hiccups

Painful and devastating hiccups may develop after high abdominal injuries, especially injuries or abscess formation close to the diaphragm. Eliminate the cause of the hiccup by reoperation, or give a mixture of morphine-chlorpromazine for symptomatic treatment.

Points to note – Chapter 37

Severe pelvic injuries are complex, know which injury needs surgery most
- study p. 156 and 468
- know when emergency laparotomy should be done on pelvic injuries: p. 111 and 113
- study the anatomy, know how to identify and control the iliac arteries during laparotomy: p. 477
- internal pelvic bleeding is controlled by gauze packing: p. 472. But do not enter a retroperitoneal hematoma

Learn to control femoral artery bleeding
- study the anatomy and incisions: p. 477
- study the surgical technique: p. 167

Injuries to the buttocks carry high risk of wound infection
- study the anatomy: p. 469
- know how to debride the deep parts of the wound track: p.473 and 480

Most pelvic fractures are reduced under traction
- learn to apply tibia traction: p. 212
- combine with pelvic sling: p. 478. Or trochanter traction: p. 479.

37 Pelvic injury

Surgical anatomy

Pelvic injuries are common wartime injuries

- Entrapment, vehicle accidents, fall from 3-4 meters: Blunt pelvic injuries are common.
- High-energy missile injuries: Suspect pelvic injury, also in cases with inlet wounds at the back, abdomen and thigh.
- Mine injuries: Suspect pelvic injury, especially in circulatory shock cases. Mine injuries are normally multi-missile – there may be more than one pelvic wound track.

Pelvic injuries are serious and complex

- **Bleeding:** The vascular network inside the pelvis is rich. Blood loss of 1000-2000 ml is not uncommon in blunt pelvic injuries.
- **Retroperitoneal hematomas:** There are numerous spaces and compartments inside the pelvic cavity where hematomas may form. The pelvic cavity may contain 2000 ml of blood with few local clinical signs.
- **External hematomas:** In the spaces between the massive muscles of the pelvis and upper thigh deep hematomas may escape diagnosis.
- **Multi-organ injuries** are common; in particular, the bladder, small intestine and rectum are at risk.
- **Infected hematomas:** Both internal and external hematomas are sources of abscess formation unless they are properly drained. The sources of infection may be perforations of the intestine. Or contamination through inlet wounds in the perineum.
- **Associated neurological injuries** may complicate the rehabilitation.

Missed diagnosis

As both internal bleeding and intestinal injury may have few early clinical signs, the extent of pelvic injury is often underestimated the first hours and days after injury. This is one main reason of the high rate of complications of pelvic injury. Do repeated clinical examinations, do exploratory laparotomy when in doubt.

Risk assessment – first things first!

As the injuries are complex, it is necessary to analyze exactly what is the main risk of complications at each stage of the management.

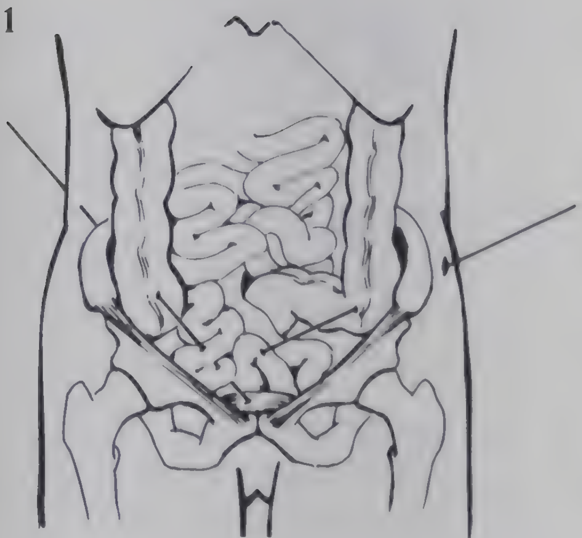
The details of emergency laparotomy: p. 155.

- **Priority one – control the bleeding – save the life:** Do not enter a retroperitoneal hematoma, the bleeding may explode. Retroperitoneal bleeding normally stops spontaneously when the hematoma has reached a certain size. However if there is bleeding into the abdominal cavity, emergency laparotomy with compression/clamping of the aorta or iliac artery may be indicated.
- **Priority two – control the bleeding – save the limb:** If the blood supply to one limb is lost, the iliac artery should be explored. Control

Sigmoidostomy: p. 384.

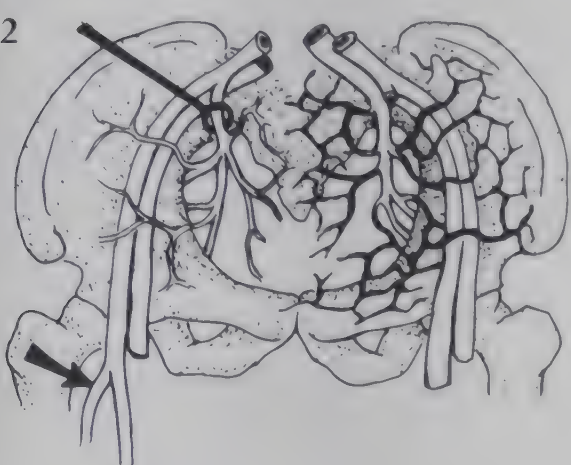
the common iliac artery/aorta proximal to the injury and the femoral vessels distal to the injury before you enter the pelvic hematoma. **Note:** Due to the many collaterals between the internal and external iliac arteries, the early signs of external iliac artery injury may be few.
- **Priority three – prevent secondary infection:** Close intestinal wounds and divert the fecal stream. Close bladder tears and decompress the bladder (suprapubic catheter). Also in major wounds of the perineum and upper thighs, diversion sigmoidostomy should be considered.
- **Priority four – manage pelvic fractures:** In unstable fractures through the pelvic ring, early external fixation will reduce the blood loss. Other types of pelvic fractures should be managed when the patient is circulatory stable.

1



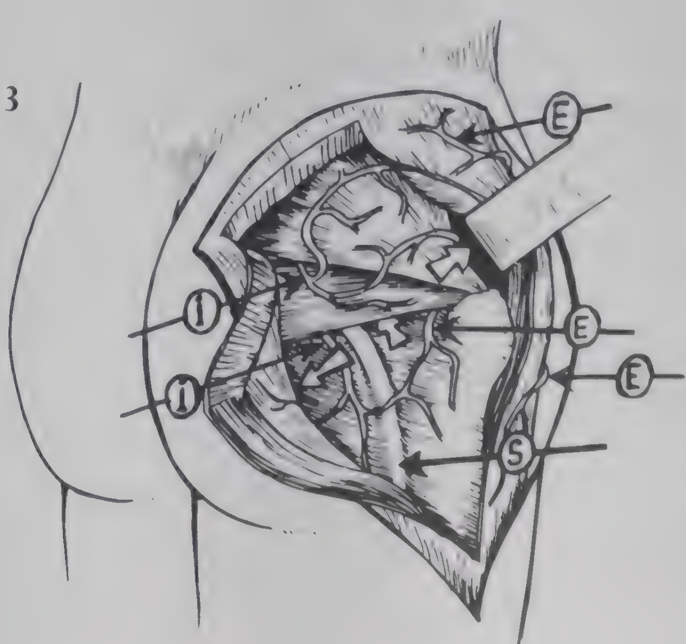
1 Associated injuries: In the upright position, the pelvis is filled with loops of the small intestine. The pelvic bone wings offer no protection against high-energy missiles. Bone fragments may be propelled by the missile into the pelvic cavity.

2



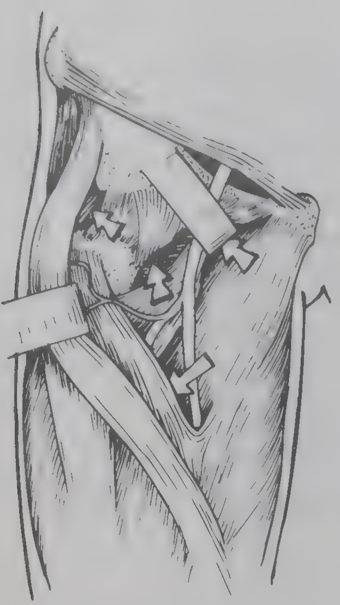
2 The pelvic vascular network: The iliac artery divides into the internal (encircled) and external iliac arteries just below the pelvic wing. The ureters cross the arteries approximately at this level. The branches of the internal iliac artery to the bladder and uterus are common sources of pelvic bleeding. Do not hesitate to ligate the internal iliac artery if the external artery is undamaged – there are copious communications between the right and left internal arteries. Note the deep femoral artery (black arrow) rising from behind the main artery: Tears of the deep artery may form hematomas deep in the proximal part of the thigh, but the injury is often missed initially.

3



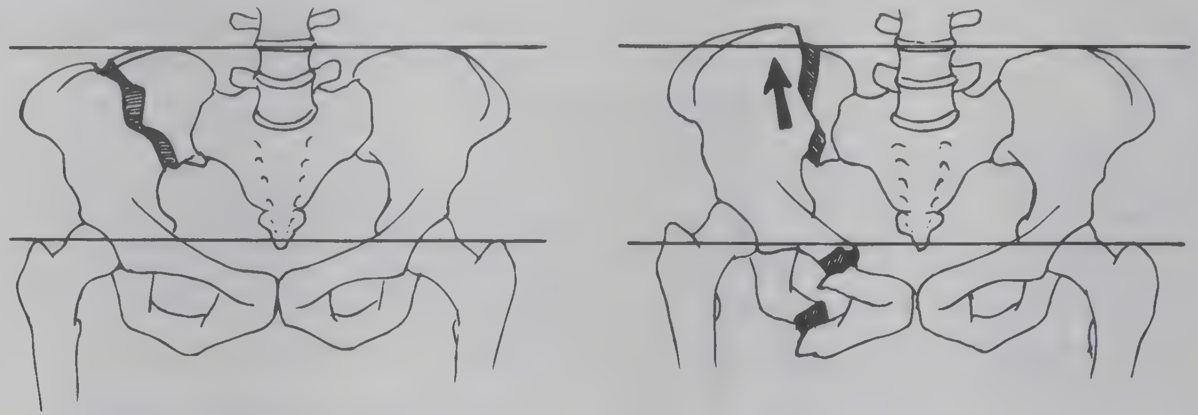
3 The vascular network of the buttocks: The superficial muscles of the buttocks are retracted to expose the arteries. There is a communicating network between branches from the internal iliac artery (i) and the external iliac and femoral arteries (E). These collaterals are one reason why some limbs may be viable despite ligature of the external iliac artery. The arrows point out the compartments where hematomas may form: between the superficial and deep layer of the buttock muscles, and in the canal of the sciatic nerve (S). **Note:** Hematomas and abscesses may also form inside the pelvis, and penetrate the multiple outlets from the pelvic cavity into the perineum and the thigh (p. 433).

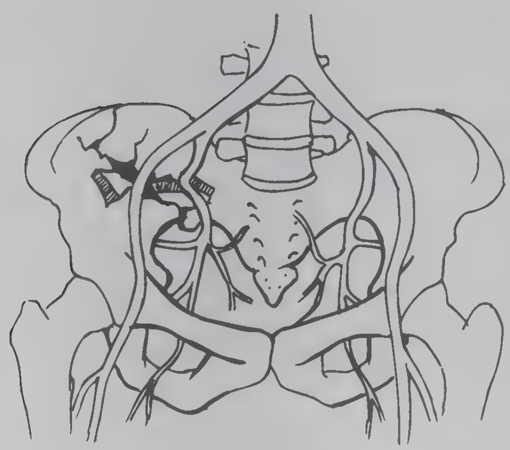
4



4 Deep hematomas of the groin and upper thigh: Hematomas of 1-2 liters may collect superficially under the strong muscle fascia of the buttock and thigh. The superficial hematomas are seldom missed, but the deep ones are: Hematomas in the deep compartments are smaller, but are still the main reason for the high rate of infected upper thigh and groin injuries. Note especially the compartments close to the hip joint: Outside the joint capsule is a fat pad (not shown in this illustration) which makes an excellent medium for infected hematomas. Also note the space between the adductor muscles (the most medial arrow), and the compartment along the femoral artery inside the adductor canal.

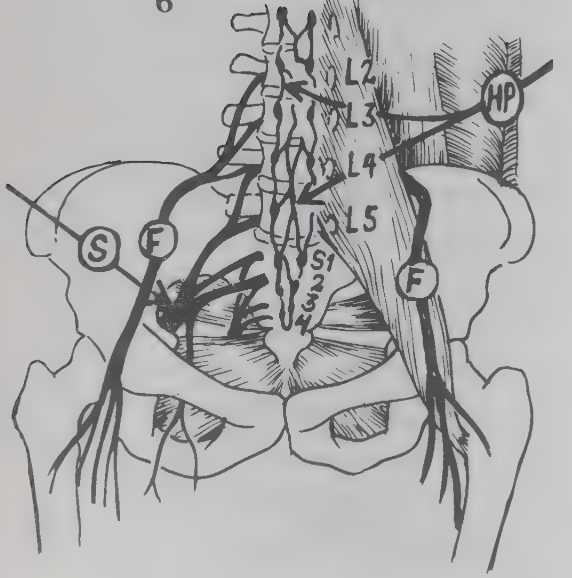
5





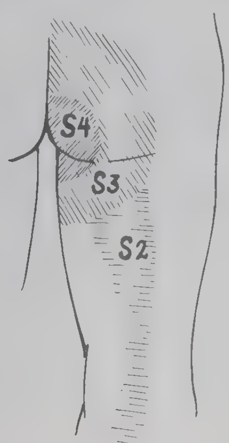
5 The pelvic bone ring: The ring may sustain one single fracture, and still be stable. Double fractures, like this vertical-shear fracture, are unstable. In high-energy fractures the "bone missiles" from the pelvic fractures may tear the vessels and organs deep inside the pelvic cavity. In this case the internal iliac artery is damaged.

6



6 Pelvic nerve injury: The nerve roots of the sacral bone form the pelvic nerve plexus. The nerve plexus is located close to the pelvic bone ring, and may be damaged by bone fragments. The main nerves from this plexus are the femoral nerve (F) to the extensor muscles of the thigh, and the sciatic nerve (S). From the hypogastric plexus of sympathetic nerves (HP) in front of the spine run the nerves for urine and stool control.

7



7 Routine: Make neurological examination of pelvic injuries! Do pinprick sensory testing of the perineum and lower limb in pelvic injuries, and test the contraction of the anal ring muscles. Loss of the sensory function of the sacral nerve roots indicates neurological damage to the bladder. Management of neurological damage to the bladder: p. 319.

Preparations for surgery. Anesthesia

Surgical equipment needed:

- General debridement set
- Instruments for abdominal surgery
- Vascular clamps
- Suction
- Ribbon gauze and large gauze packs
- Instruments for bone and amputation surgery
- Bone traction equipment including eye screws
- Plaster of Paris
- Canvas sling for stabilization of pelvic fractures
- If available: external fixation set

Anesthesia

Spinal anesthesia works well in pelvic injuries and low midline laparotomies. The level should reach Th6-8 (between the umbilicus and sternum) to prevent pain during manipulation of the peritoneum. The problem is the hypovolemia often present in major pelvic injuries: The blood loss may be underestimated, and spinal anesthesia may cause circulatory collapse if the hypovolemia is not compensated for. If you suspect major pelvic bleeding or hematoma, ketamine is the anesthetic of choice. Penetrating injuries of the upper thigh and buttocks: If the deep injury is normally more extensive than expected, proper exploration cannot be done under local anesthesia.

Preparations for surgery

> High risk of anaerobic infection: Give one i.v. dose of potent antibiotics and metronidazole before surgery on all high-energy penetrating injuries.

On the operating table: Wash a wide operating field from the mid-thigh to the sternum. Cases with perineal injury, bladder and rectal injury are managed in the gynecological position. The abdominal exploration and repair are done before the inlet wound track is debrided and drained.

Penetrating pelvic injury

Unstable pelvic fractures, such as "open-book" injury and vertical-shear fractures, will continue to bleed until they are reduced and stabilized.

Exploration of the femoral artery and vein: p. 477.

Emergency laparotomy: p. 155.

Consider autotransfusion if there is no rectal injury: p. 270.

The priorities for surgery

Step one – control bleeding, manage hypothermia and circulatory shock before you start on organ repair

- External control: Pack deep pelvic wounds with gauze pads or ribbon gauze. Flush infusions and try to arrange transfusions of fresh whole blood. If you cannot stabilize the circulation, the case is one for laparotomy:
- Surgical exploration and vascular control: First check the lower limb circulation. If one leg is cool, suspect injury to the common iliac artery or the external iliac artery. If both legs are perfused, he is probably bleeding from the internal iliac network – expect a pelvic retroperitoneal hematoma. In any case: Do low midline laparotomy, tilt the head end downwards and retract the small intestines. Compress the distal aorta against the spine or clamp the iliac artery before you enter the hematoma. **Note:** Venous and backward artery bleeding is controlled by clamping of the femoral vessels through a standard groin incision. If the bleeding is heavy and you cannot identify and control separately the bleeding source, pack the pelvic cavity with large gauze pads. **Notice** the one-hour limit on surgery in unstable cases: Time-consuming reconstructions of the limb blood vessels may be fatal. In emergencies you may leave the vascular clamps on the vessels without tying the ligatures. Close the abdomen and concentrate on warming and volume therapy.

Step two – manage associated abdominal injuries

- Injury to the colon: Do not miss injuries on the posterior wall – mobilize the colon and explore it well, especially in pelvic fracture cases. Close the intestinal wounds, and divert the fecal stream – either by tying the colon (emergencies), or by diversion enterostomy. Dilate the anus and wash the rectum.
- Urinary tract injuries: Close them carefully. Drain the retroperitoneal space outside the bladder. Decompress the bladder by urethra catheter **and** suprapubic catheter to prevent urine leak.
- Vaginal tears: If they bleed much, insert a gauze tampon through the tear. Otherwise the tear is debrided, left open and used to drain the retroperitoneal compartments of the pelvic cavity, or the abdominal cavity (the rectovesical pouch).

Step three – manage associated fractures: Pelvic fractures heal well – the blood supply is rich. As there are massive muscles encircling the pelvic bone ring, covering the fracture with viable soft tissue seldom presents a problem.

- At the time of primary surgery – concentrate on measures to prevent fracture infection: Insert drains from outside and inside the fracture, prevent contamination by urine and feces. In emergencies, the debridement and fracture reduction may well be delayed by 24-48 hours.

- When the patient is circulatory stable – manage the fracture: Exact debridement and drainage of the muscle tissue deep in the wound track are essential. Exact reduction of the fracture is not necessary; rough reduction (traction, canvas sling) helps reduce bleeding and pain.

8

8 Missile injuries of the buttock: The muscle volume is massive and necrotic tissue left over deep in the wound track often causes infections, also anaerobic infection (gas gangrene). Thus all deep wounds of the buttocks – even after low-energy missiles – should be fully explored. Extend the inlet wound in a wide longitudinal exploratory incision through the muscle fascia. Explore and drain the compartments between the superficial and deep muscles well (ill. 3). Do not close the fascia incision, but leave it wide open with gauze drainage to prevent anaerobic infection. Do not manipulate depressed fracture fragments as that may cause severe bleeding from the venous network lining the inside of the pelvic bone ring. Control fracture bleeding: Apply a long ribbon gauze tampon through the fracture to control bleeding. Let the tampon out through the fascia incision. Leave the tampon for two days, then withdraw it stepwise as you watch the patient for signs of rebleeding.

9

9 Exploration of the sciatic nerve: Primary nerve repair is not done in wartime injuries, but debridement of the nerve and surrounding tissues must be done to prevent infection. The standard incision for sciatic exploration is just behind the trochanter of femur. Split the fascia along the fibers and split the superficial layer of the buttock muscles immediately behind the trochanter, retract the muscle and identify the nerve by careful blunt dissection. **Notice:** A branch of the internal iliac artery runs together with the sciatic nerve – hematoma in the sciatic nerve canal indicates nerve injury. Split the epineurium and explore the nerve bundles. Management of nerve injuries: p. 231.

Hip joint injury

The management of joint injuries: p. 217.

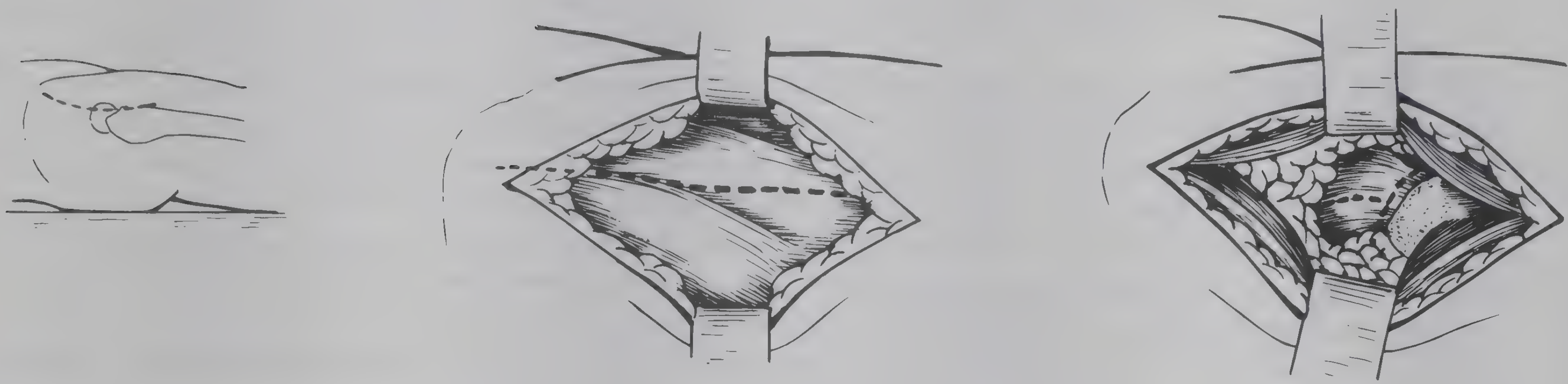
The degree of cavitation depends on the length of the wound track: p. 517.

Prevent osteomyelitis!
The final function after fractures of the hip joint is not only fracture reduction and fixation: A hip joint with major bone derangement may still have reasonable function – provided it heals without infection. The high rate of osteomyelitis after penetrating hip joint injuries is a result of poor primary management:

- The volume of muscle tissue surrounding the joint is great. The missile wound tracks are long enough (15-20 cm) to let most high-energy missiles fragment fully. The cavitation and tissue destruction deep in the wound track (close to the joint) are extensive for all types of common rifle ammunition. Consider this effect of the weapon physics: Extensive deep exploration is necessary.

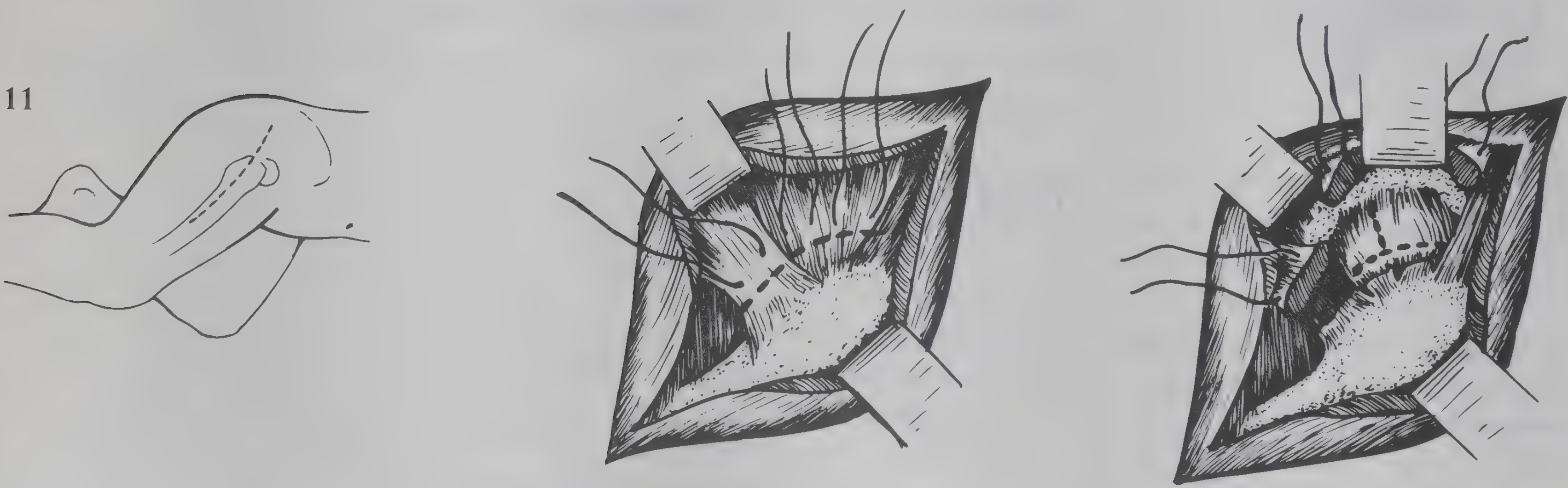
- There is a rich vascular network in the deep compartments around the hip joint (ill. 3). This helps the fracture to heal well, but it also causes hematomas: Drain them!
- There are several deep compartments close to the joint where hematomas may form. However small, they may cause deep abscesses – unless explored and drained. Study the anatomy well (ill. 4).

10



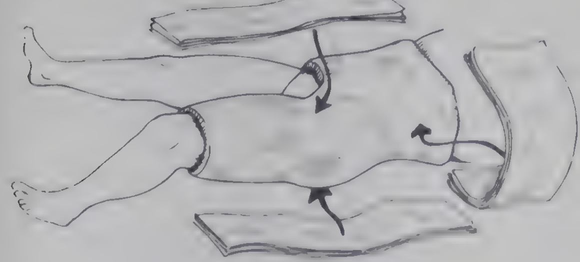
10 Exploration of the hip joint – antero-lateral approach: This is the easiest access to the joint. The incision is done through the skin from below the pelvic spine and in front of the trochanter. Sweep away the fat, incise the muscle fascia, and split the muscles by blunt longitudinal dissection. You now enter the compartment surrounding the anterior part of the joint where deep infections may form. Take particular care to resect necrotic fat tissue, and drain this compartment well. You may inspect the joint through a cross-wise incision through the fibrous capsule (dotted line).

11



11 Exploration of the hip joint – posterior approach: Missile injuries entering the joint from behind are best explored by a posterior approach. The skin and fascia are split, and stay sutures tied through the deep muscles close to their attachment to the trochanter. Split the muscles close to the bone, retract them and expose the joint capsule (for reasons of illustration the fat pad outside the capsule is not drawn). Enter the joint through a cross-wise incision through the capsule (dotted line).

12



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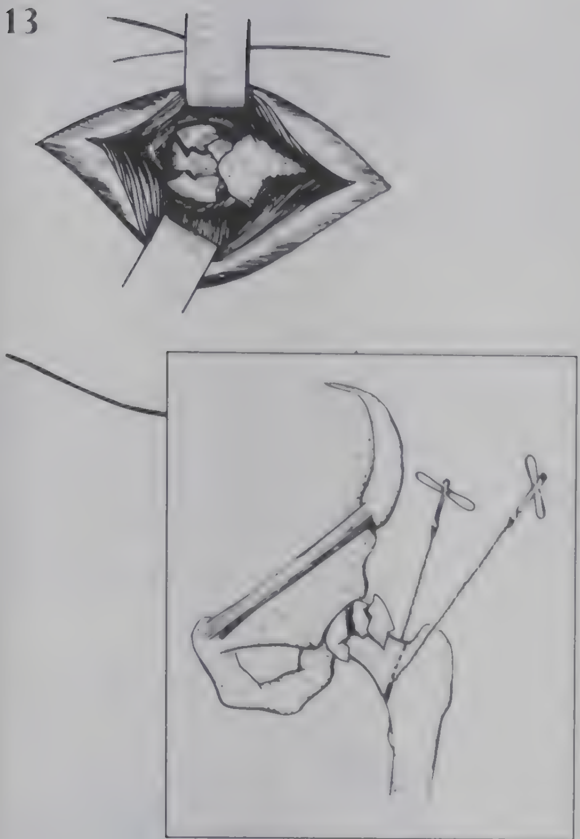


12 **Trueta plaster management of open hip joint injuries:** The Trueta method (p. 208) provides both drainage and fracture fixation. The "half pant spica" here illustrated stabilizes fractures of the proximal femur, the hip joint and pelvic fractures. Applied early, it prevents the flexion contracture that often develops after hip joint injuries, and makes early mobilization and evacuation of the patient possible. The procedure: Extend the inlet wound, explore and debride the joint/the fracture. Leave the fascia incision open as fasciotomy; fill the wound/incision with fluffy dry gauze from the deepest compartment up to the skin surface. Pad the bony prominences of femur and pelvis. With the hip joint at about 15 degrees flexion, three slabs – one anterior, one posterior and one circular – are applied. Then the circular plaster is applied and the spica molded well.

13 **Primary Girdlestone operation for compound fractures of the femoral head and neck:** The vascular supply to the head and neck of femur is poor. Some weeks after femoral neck fractures, the femoral head may become soft and waxy. X-ray films may show the destruction of the head of femur 1-3 months after injury. Missile fractures of the hip joint with major derangement of the head and neck of femur are therefore best managed with primary resection – the Girdlestone operation: Do the surgery with leg traction for better exposure of the joint. In this case the fracture is exposed through an anterolateral incision (ill. 10). Remove bone fragments and resect the neck of femur (Gigli saw or chisel). Cover the resected end of femur with a flap of capsule or muscle. Drain well. Either tibial traction is applied for 4-6 weeks, or the Trueta method is applied and the patient is mobilized the next day. With early and active physical training, the Girdlestone hip joint will become surprisingly stable and painless.

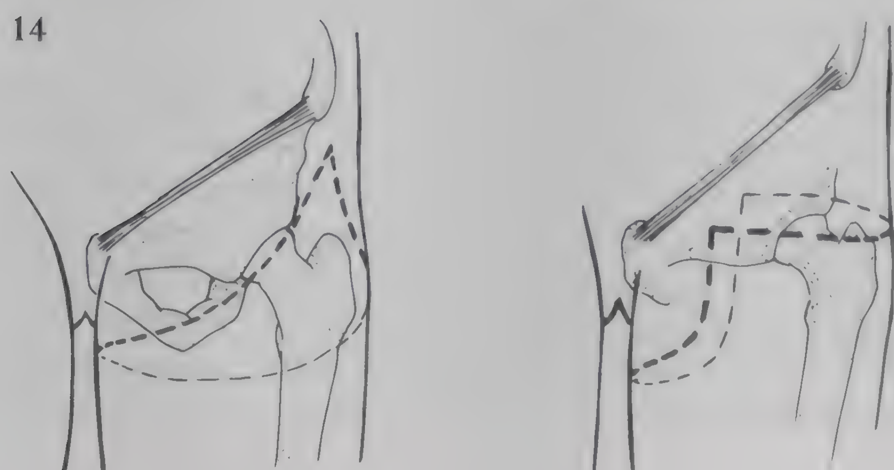
Hip joint disarticulation

Hip joint disarticulation is a very bloody procedure: Have plenty of blood to transfuse.

10-cm limit on femur amputation stumps

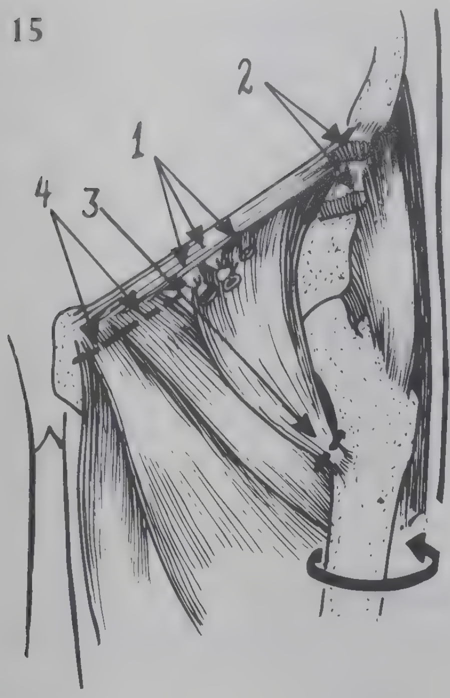
From a functional point of view a femur stump – even a short one – is preferable to hip joint disarticulation. But a femur stump shorter than 10 cm cannot control a prosthesis, and is of little value. Hip joint disarticulation may be the treatment of choice in cases with traumatic high thigh amputations, and in anaerobic infections of the upper thigh and groin region.

14



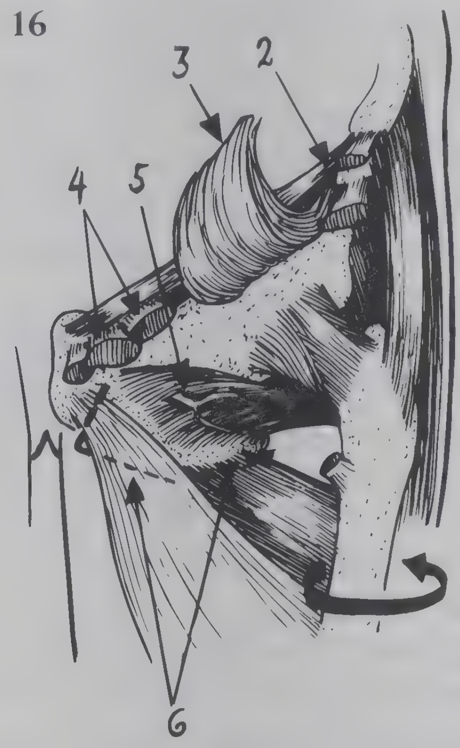
14 **Hip joint disarticulation – the skin incision:** the standard skin incision. Depending upon the injury, both posterior-anterior and medial-lateral flaps may be designed.

15



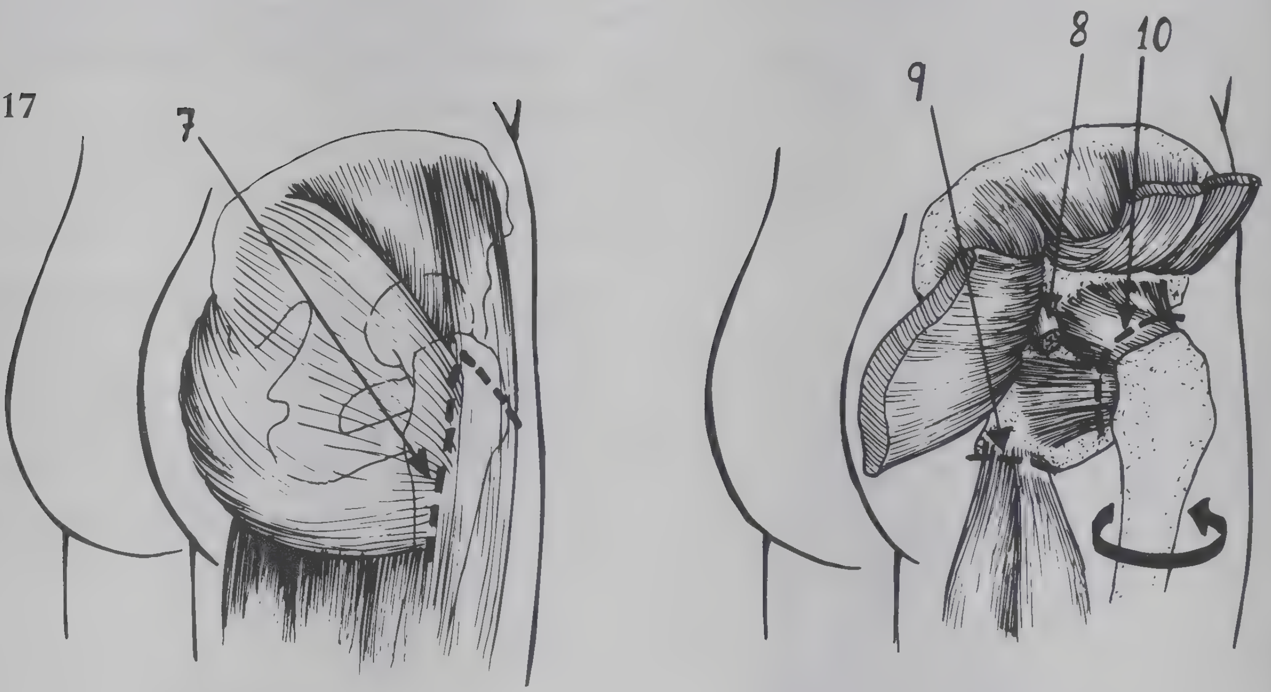
15 The disarticulation – step one: (1): We recommend controlling the iliac vessels through a separate incision to reduce the blood loss. Then (1) tie the main femoral vessels. (2, 3): The flexor muscles are cut close to the bone to reduce bleeding. (4): Rotate the femur outwards and cut the adductors close to their pelvic attachment.

16



16 Step two: Identify and tie the obturator artery medial to the hip joint (5) before you cut the adductors. The artery may otherwise retract into his pelvis and cause internal bleeding. Rotate the leg outwards for easier dissection. (6): Then cut the deep adductors close to the pubic bone (dotted line).

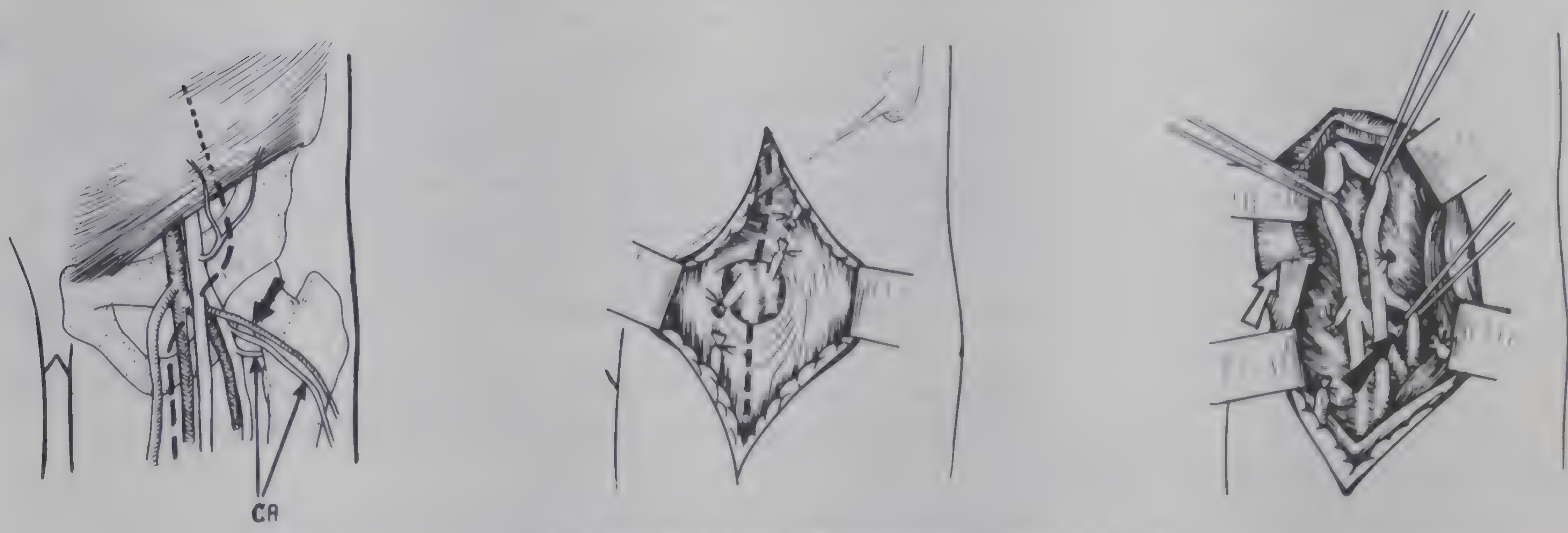
17



17 Step three: The thigh fascia is incised and (7) the buttock muscles are cut at their attachment to the trochanter. (8): The sciatic nerve is identified and cut sharply as proximal as possible. Inject local anesthetic along the nerve stump. (9): Rotate the femur inwards and cut the hamstring muscles close to their pelvic origin. (10): The joint capsule is incised and the head of femur released. The wound is left open for at least five days, then the stump is closed. The large posterior muscle-skin flap is trimmed to fit the groin incision. The buttock muscles are sutured to the inguinal ligament over wide-bore drains.

Exploration of the main arteries

18



18 Exploration of the lower part of the iliac artery: The skin incision is S-shaped. Identify and divide the superficial veins. Then extend the fascia incision in the distal direction and proximally through the inguinal ligament and the abdominal muscles (dotted line). Divide the minor vessels in front of the femoral artery. Approximately 5 cm below the inguinal ligament, the deep femoral artery rises from the posterior side of the femoral artery. Identify and tie the circumflex vein running between the superficial and deep femoral artery (big black arrow). Also identify the circumflex arteries (CA) – they may bleed considerably.

The risk of secondary gangrene after ligature of the iliac arteries depends on the level of ligature, the age of the patient and the duration of the circulatory shock. For details: p. 188.

19

19 Exploration of the upper part of the iliac artery: A low midline incision is extended above the umbilicus. The left or right colon is mobilized (p. 362) and retracted. Identify the ureter (black arrow) before you split the peritoneum: It crosses the iliac vessels approximately where the artery divides. If there is a large and expanding retroperitoneal hematoma, compress or clamp the aorta/the common iliac artery proximal to the injury before you enter the hematoma. If it still bleeds, compress/clamp the femoral artery in the groin.

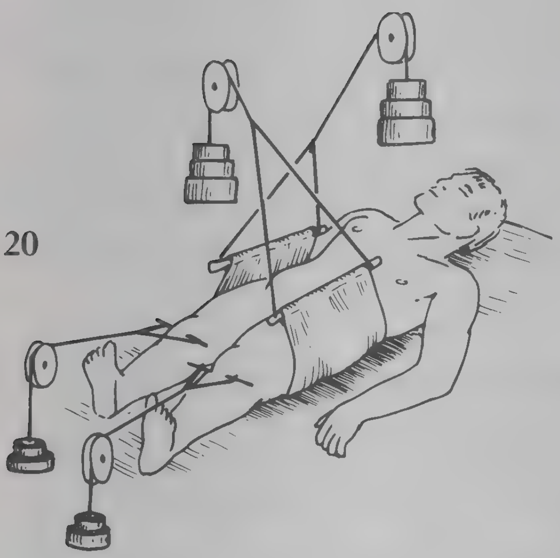
Pelvic fractures

First priority: Control bleeding, support the circulation. A fracture hematoma may contain 2000 ml. Pack open bleeding fractures with ribbon gauze through the inlet wound.
Second priority: Manage associated injuries. Fracture fragments may have torn the urethra, bladder, rectum, the iliac vessels and the main nerves. Careless manipulation of an unstable fracture may add to the initial damage.
Third priority: The fracture management.

- Pubic bone fracture – urethral tear: If there is blood in the opening of urethra, you cannot pass a urethra catheter. Explore the urethral injury (p. 436) before you manipulate the fracture.
- Pubic bone fracture – bladder injury: Hematuria and urine phlegmon indicate a bladder tear. Explore the injury through a low midline incision. Split the peritoneum in front of the bladder (p. 435) and identify the fracture. Reduce the fracture under direct vision. **Notice:** Pelvic fractures may temporarily block the bladder function even if the bladder itself is not damaged. Leave an indwelling bladder catheter for 3-5 days in all major pelvic fractures.
- Injury to the rectum: Rectal exploration is routine. Blood indicates intestinal injury.
- Sciatic nerve injury must be explored and the fracture reduced under direct vision if there is a significant loss of nerve function on admission.

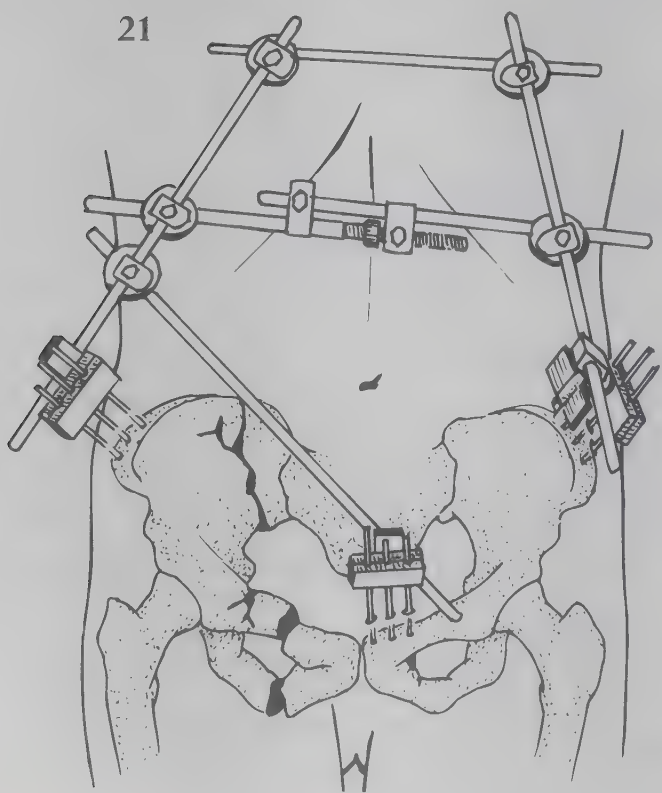
Evacuation of unstable and bleeding pelvic fractures:
- Double i.v. lines.
- Insert bladder catheter.
- Reduce the fracture roughly by manual traction on both legs.
- Maintain the leg traction while turns of broad elastic bandage or sheets of cloth/canvas are tightly tied around the pelvis.
- Apply circular turns of plaster outside the compressive dressing, mold the plaster well to fit the contours of his pelvis.

20



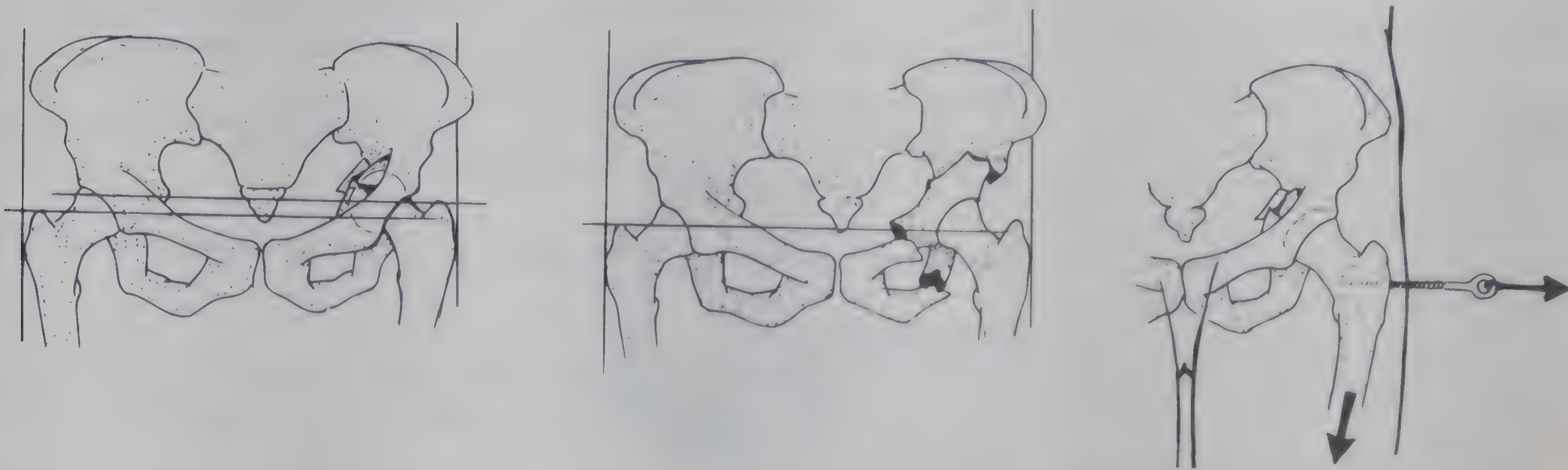
20 Reduction of compound pelvic fractures: A canvas sling with crossed traction will compress his pelvis. The traction weights should nearly lift his pelvis from the bed. Make a split in the midline for toilet purposes. Double tibial traction helps achieve good fracture alignment. The combined sling and leg traction is used for four weeks, then a hip plaster spica is applied (ill. 12) and the patient is mobilized. Note that the plaster spica should reach his lower chest in order to reduce the weight load upon the pelvic ring.

21



21 The external fixation apparatus may be used in unstable double fractures.

22



22 Fractures with hip joint displacement – combined traction: Unequal length of the legs, and pain on hip joint rotation indicate penetration of the acetabulum or displacement of the acetabular fragment. Even minor derangements in the acetabulum should be reduced by traction: Apply tibial traction. Then make a small incision over the trochanter; make a hole in the bone with an awl, and insert an eye screw at least 3 cm into the trochanter. Combined tibial (10 kg)-trochanter (5 kg) traction is used for 3-4 weeks. Then a high hip plaster spica including his thigh and lower chest is applied (ill. 12), and he is mobilized.

Complications of injury and surgery

Paralytic ileus and retention of urine

Even with damage to the intestinal or urinary tract, the bowel and bladder function is normally lost for some days after major pelvic injuries. Leave the bladder catheter for some days, clamp it at intervals. Monitor the bowel sounds. Early mobilization and rectal rubber tube stimulate the bowel function. If the bladder and bowel function does not improve within 4-5 days after injury/surgery, suspect pelvic nerve damage or a missed organ injury: Consider exploratory laparotomy.

Continuous bleeding, rebleeding or hematoma formation

Infection may cause rebleeding; the risk period is 5-10 days after the injury.

- Moderate rebleeding: Explore the wound tracks to identify, debride and drain the necrotic tissues left over from the primary surgery.
- The rebleeding may be massive: Emergency laparotomy with clamping of the distal aorta must be done. The mortality rate is high.

Emergency laparotomy: p. 155.

Infection and abscess formation

The clinical signs arise 5-10 days after the injury:

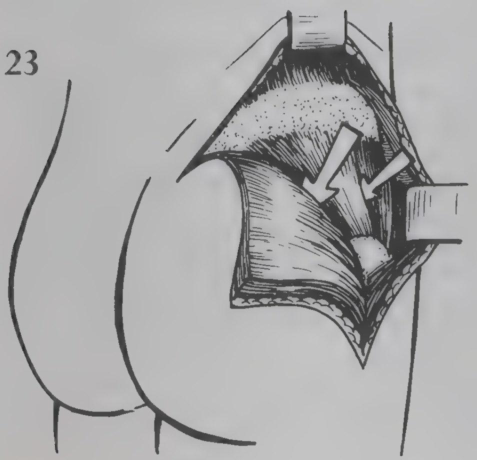
- Worsening of the general condition
- Abscess temperature (p. 459)
- Local swelling of the groin, above the pubic bone or in the perineum and scrotum (p. 432-433)

- Manual examination of the vagina and rectum may identify local swelling
- Consider diagnostic puncture of the rectovaginal pouch: Aspiration of pus through a large-caliber needle is diagnostic
- Test the femoral pulse beat and the neurological function of the legs: A major abscess may compress iliac vessels or nerve roots

There is only one management: midline exploratory laparotomy without delay.

Urine phlegmon
Bruising and swelling above the pubic bone, in the perineum or scrotum may be a sign of urinary tract tear with free leaking of urine. Repair the tear and decompress the bladder.

23



Buttock abscess and gas gangrene
They may develop in deep wound tracks. The reason is poor primary debridement and drainage. After missile injuries buttock abscesses may be formidable, and the patient may deteriorate rapidly.

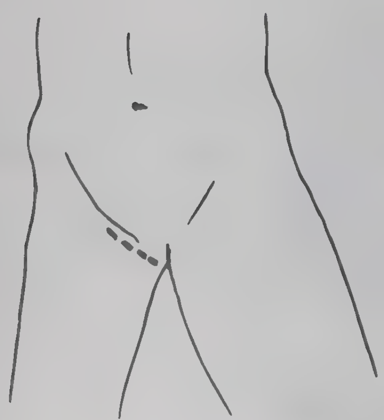
23 Exploration of the deep structures of the buttock: Wide dissection is necessary. Release the buttock muscles from the pelvic wing through a V-shaped incision. By blunt and chisel dissection the muscles are detached from the pelvic bone, retracted and the deep segments of the wound track exposed. Now do the debridement and drainage that should be done during the primary surgery. Do not compromise on the debridement – the risk of gas gangrene and other aggressive anaerobic infections is high: Do extensive excisions of all non-viable muscle and leave the wound wide open. The tensor fascia lata muscle flap may provide soft tissue cover for the hip joint. But only rotate the flap when the infection has settled.

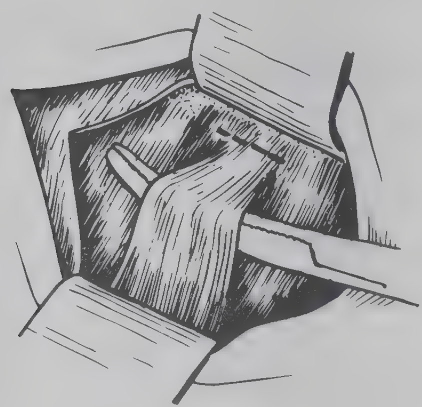
Muscle rotation flaps: p. 201.

Hip joint arthritis and abscess formation
Pain originating in the hip joint is normally referred to the groin area. Increasing groin pain, flexion contracture of the hip, pain on passive rotation of the femur and fever – all indicate hip joint infection: There may be an abscess in the compartments close to the joint or infection inside the joint. In any case exploration and evacuation of the infection should be done immediately (ill. 4).

Washing of infected joints: p. 220.

24





24 Adduction contracture of the hip joint may be the result of poor training after surgery, and protracted and painful rehabilitation. Palpate the tendons while you force the leg into passive abduction: If you feel the tendons as tight strings under the skin, first do adductor tenotomy. The adductor tendons are cut close to the pubic bone under extension and abduction of the hip joint. Cut the muscle close to the pubic bone to avoid damage to branches of the obturator artery.

25

25 Extensor tenotomy: If adductor tenotomy did not release the joint, extensor tenotomy is also done: Split the muscle fascia and cut the extensor close to the attachment to the pelvic bone. **Notice:** After tenotomy, the tendons will reattach without suture and the patient will gain full strength after some months of training. **Notice:** Without effective analgesia and intensive passive and active exercises after the tenotomy, the contracture will soon redevelop.

Points to note – Chapter 38

Of all casualties managed at forward clinics, one out of four is an upper limb case; better study the complete chapter carefully.

Study the anatomy sections to know
- the standard incisions for exploration and debridement
- the deep spaces that should be drained

Specially note the exact localization of main nerves and arteries
- to avoid accidental nerve injury during surgery
- to be able to identify and control bleeding arteries: p. 120

Learn to do complete fasciotomies
- of the arm: p. 490
- of the forearm: p. 502
- of the hand: p. 503

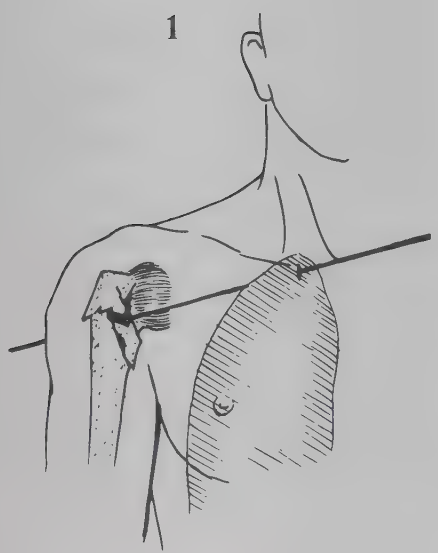
38 Upper limb injury

Preparations for surgery

Surgical equipment
- General debridement set
- Bone nibbler, chisel, Gigli saw
- Drill, Steinmann pins, eye screws, soft steel wire
- Plaster of Paris (rolls of 10 cm and 15 cm)
- If available: external fixation set
- Instruments for vascular surgery: p. 59
- Suture materials: p. 60

Soap washing on admission: Most limb cases have low priority for surgery. In a mass casualty situation there may be a delay of hours between the admission and surgery. But the disinfection should not be delayed: Wash the wound field on admission. Also instill dilute soap solution into deep wounds.

1



1 **The operating field – beware of associated injuries:** Lung injury, damage of major subclavian vessels, and brachial plexus nerve injuries are often associated with upper limb injuries. Note the level of the top of the lung. In patients with old TB lung infections, the pleura may even rise above the level of the first rib. Bone fragments from high-energy shoulder and clavicular fractures may also penetrate the pleura. Or a high-energy missile may penetrate both the upper limb and the abdominal wall.

The limb wound is more extensive than you imagine
The shock wave from a high-energy missile travels proximally and distally along the muscle bundles of the upper limb. The shock wave may even cross the joints (p. 80). Wide fasciotomies and exploratory incisions are necessary: Wash the whole limb from the neck to the fingers. Do not drape the hand: During surgery you have to monitor the skin color and temperature of the fingers to control the blood perfusion of the limb.

Vein grafting: p. 192.

If you suspect vascular injury: Prepare for vein grafting. Wash the donor area on an uninjured limb.

The position on the operating table
- Shoulder surgery: The patient is in half-side or side position with a sandbag under the scapula. Work under arm traction – manual or plaster traction: It helps realign the anatomy in major injuries.
- Arm/forearm/hand surgery: The patient is in the supine position with the arm in abduction on a separate "arm table". Work under traction in major cases.
- Hand surgery: As the fingers flex spontaneously, the access to the palm is difficult without an assistant. Make a "lead hand": Cut a hand with five broad fingers from a thin plate of lead (20 cm x 20 cm). By bending the lead fingers around the fingers of the patient, you get a steady assistant.

Control the bleeding

- Ban the tourniquet: During the field management, evacuation and in the clinic any limb bleeding is better controlled with tight compressive bandages.
- Apply a BP-cuff on the arm before you wash the operating field. Inflate it if bleeding occurs during the surgery.
- Finger surgery: Tie a thin plastic catheter tightly around the base of the finger, fix it with a clamp.

Anesthesia

- Major and urgent cases are done under ketamine anesthesia. Add diazepam 10-20 mg i.v. for muscle relaxation during fracture management.
- Non-urgent fracture cases: Consider brachial plexus or axillary nerve block for better muscle relaxation. You may add ketamine if the surgery is done above the anesthetic level.
- I.v. regional anesthesia is not recommended in primary surgery and debridements: The bloodless field makes it impossible to assess which tissue is necrotic and which is viable. In secondary procedures, reconstructive hand surgery, wound closure etc., the method is useful.
- Isolated finger injuries are managed under finger nerve block anesthesia.

Shoulder and arm injury

Basic life-saving surgery: p. 130 and 160.

Reasons to do primary amputation: p. 239.

Multi-injury patients

- Basic life support: To re-establish the limb blood circulation is more important than limb surgery – control external and internal bleeding, start volume therapy, keep the patient warm.
- Basic life-saving surgery: If the patient is unstable, extensive limb surgery is a hazard. Reduce the primary limb surgery to a minimum – do fasciotomy, reduce and splint fractures, drain the wounds, but delay the debridement until the patient is stable.

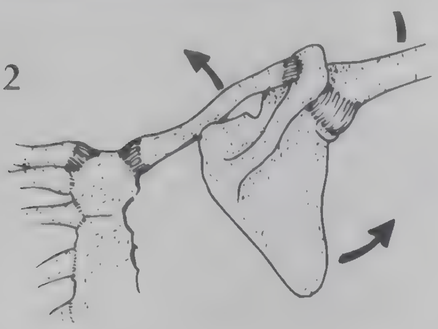
Major limb injuries

Cases with lengthy circulatory shock and limb hypoperfusion carry high risk of secondary infection, septicemia and a poor ultimate result. Collect exact information regarding the circulatory state after the injury. Consider primary amputation.

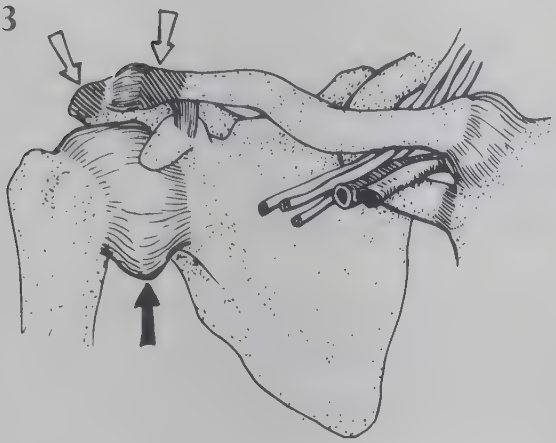
"The hand is man's extension of the brain"

To obtain the best possible hand function is the main objective of shoulder and arm surgery.

Surgical anatomy

2


2 The shoulder girdle is a four-in-one joint: The joint between clavicle and sternum, between clavicle and scapula, between scapula and chest wall, and the shoulder joint itself – all contribute to the mobility of the arm. Abduction and forward extension of the arm: There is a sliding rotation of scapula on the chest wall. A "stuck scapula" will grossly limit arm movements.

3


3 The shoulder joint: The glenoid of the shoulder joint is rather flat so as to make a wide range of arm motion possible. This wide motion is possible only at the cost of stability: Reconstruct the glenoid well, even minor fracture derangements may cause secondary instability of the shoulder. There are strong ligaments between the distal part of the clavicle and the bony prominences of the scapula. In comminuted fractures you may resect the clavicle distal to this ligament (the shaded parts, arrows) and still maintain the shoulder girdle stability.

The "frozen" shoulder is a common complication of shoulder injury and surgery: For reasons of joint mobility there is a slack of the joint capsule under the joint (black arrow). This slack will contract when the joint is immobilized, resulting in blocked joint rotation and abduction – the joint is "frozen". For this reason pendulum and abduction exercises should start within 3-4 weeks after the shoulder injury. The first clinical sign of contracture of the capsule is lost outward rotation of the humerus.

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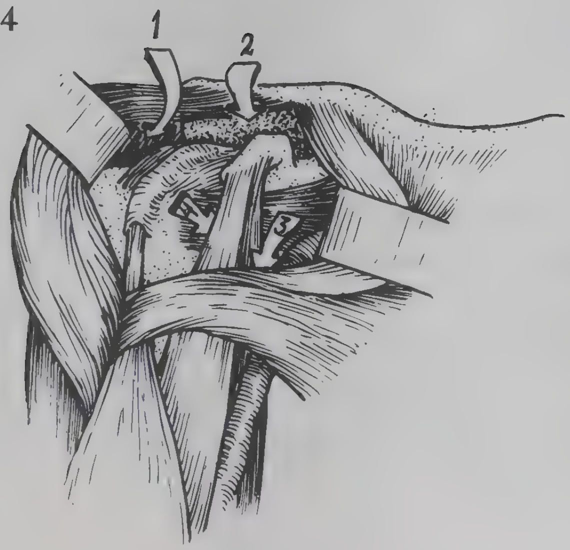
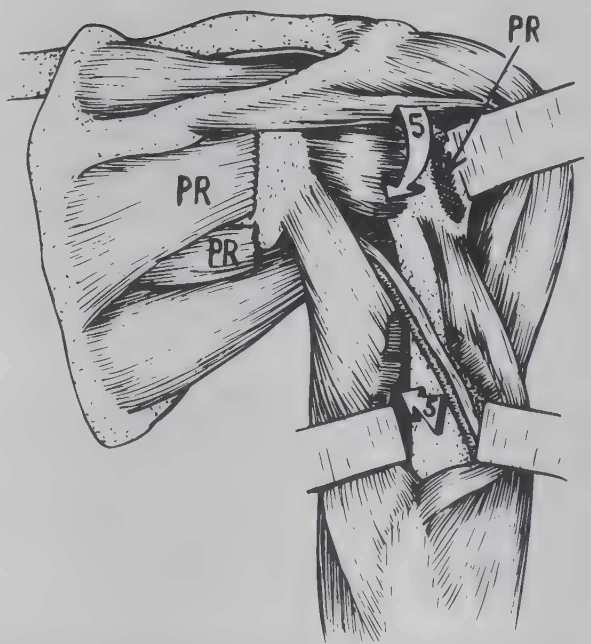




4 Compartments where hematomas form: The blood supply to the shoulder and arm is rich and wounds normally heal well. The main problem is infected hematomas – there are particular deep spaces and compartments that should be drained: (1) – between the deltoid muscle and the head of humerus. (2) – under the acromion. (3) – under the big breast muscle along the bundle of nerves and vessels down the arm. (4) – under the joint between the capsule and elbow flexors. (5) – along the radial nerve posterior to the humerus under the big extensor muscle. (For reasons of illustration, the posterior shoulder rotators, PR, are shown to be cut.)

The neurological examination: p. 120.

Identify vascular injury by neurological examination
Together with the main arteries run the nerves. Loss of nerve function after missile injury thus indicates the track of that missile inside the tissues. If the nerve is damaged, there is also risk of vascular injury.

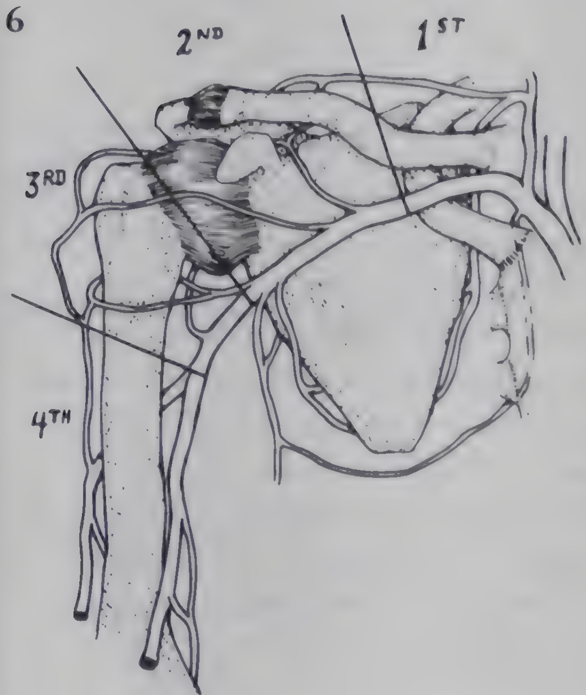
5

5 Combined artery-nerve injury

- Axillary injury: The three main nerves run close to the main vessels. If there is loss of nerve function, explore the axillary artery.
- Medial arm injury: The median and ulnar nerves are close to the brachial artery. Loss of nerve function from one/both of these nerves indicates brachial artery damage.
- Dorsal/lateral arm injuries: The deep arm artery (PA) runs together with the radial nerve close to the bone. Loss of radial nerve function indicates that the missile track is close to the deep artery.

Beware of the two levels where vascular nerve injuries are common: Above the axilla the nerve bundle passes between the first rib and the clavicle lying just 2 cm under the skin. It may be hit by the missile, bone fragments or compressed by displaced clavicular fragments. Also in humerus shaft fractures the radial nerve (RN) may be torn by the missile, by bone fragments, or compressed by hematoma and fracture callus.

6



6 Artery obstruction and the risk of gangrene: The risk of gangrene after artery injury and ligature depends upon the level of artery obstruction.

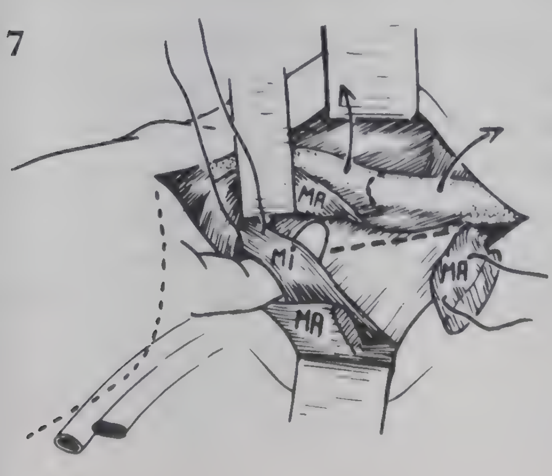
- The first part of the artery: Several collateral arteries carry blood to the arm. Ligature of the subclavian artery in young patients normally does not lead to gangrene.
- The second part of the artery: The collaterals have a small caliber and cannot carry the arm's blood supply. One out of four patients develops arm gangrene after ligature of this part of the artery. **Notice** the two arteries together with the axillary nerve running around the neck of humerus; they contribute to the hematomas forming around the neck of humerus.
- The third part of the artery: Artery injury proximal to the deep artery should be reconstructed if possible. The risk of distal gangrene after ligature is high.
- The fourth part of the artery: Ligature of the brachial artery distal to the deep artery causes arm gangrene in one out of four patients.

Exploration of shoulder injury

Assessment and management of vascular injuries: p. 187.
Management of nerve injuries: p. 231.

> The debridement of muscle tissue around the shoulder should be limited due to the rich blood supply. Concentrate on exact exploration of the main vessels and nerves. And on proper deep drainage.

7



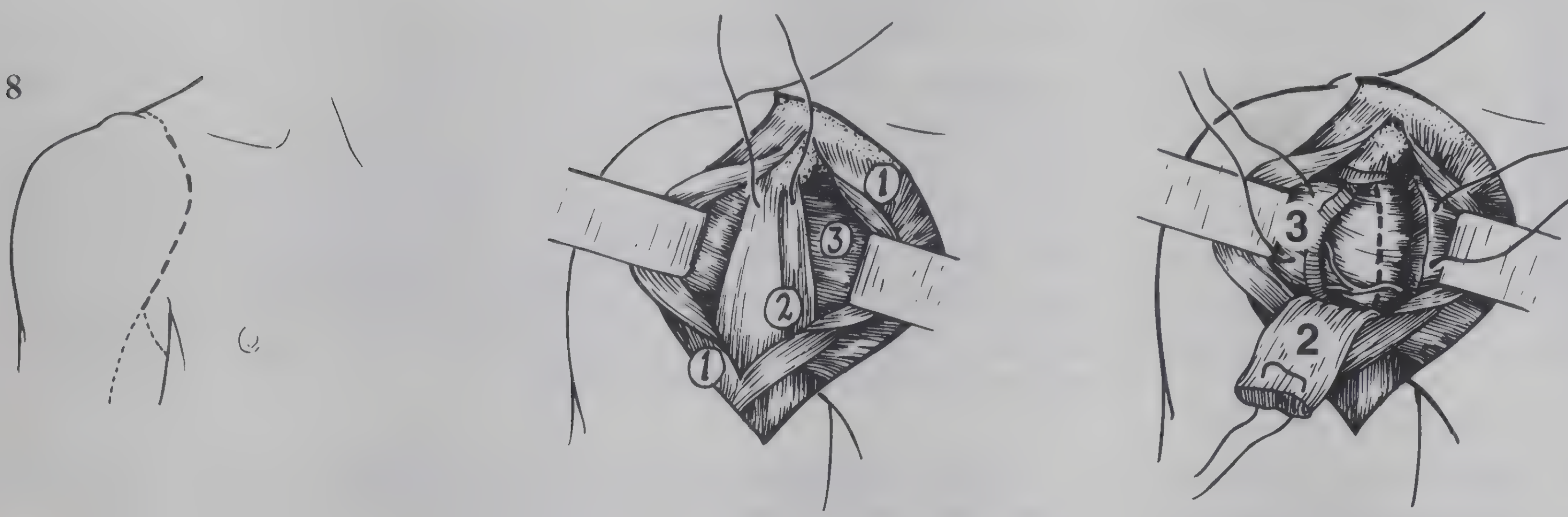
7 Exploration above the axilla: The subclavian vessels and the nerve bundle are explored through an incision 1 cm below the clavicle. The big breast muscle (MA) and the small one (MI) are cut close to their attachment to the humerus and retracted (note the stay sutures). Split the fascia under the muscles along the dotted line – beware: The subclavian vein and top of the lung are just underneath the fascia. Push the vein downwards and the nerve plexus upwards by blunt dissection. Run rubber bands around the artery and control it.

- Injuries close to the midline: Cut and retract the clavicle to expose the central part of the artery. Before splitting the bone, drill two holes 2-3 cm apart, and cut the bone with Gigli saw between the drill-holes.

- Exploration towards the axilla: Extend the skin incision along the border of the deltoid.

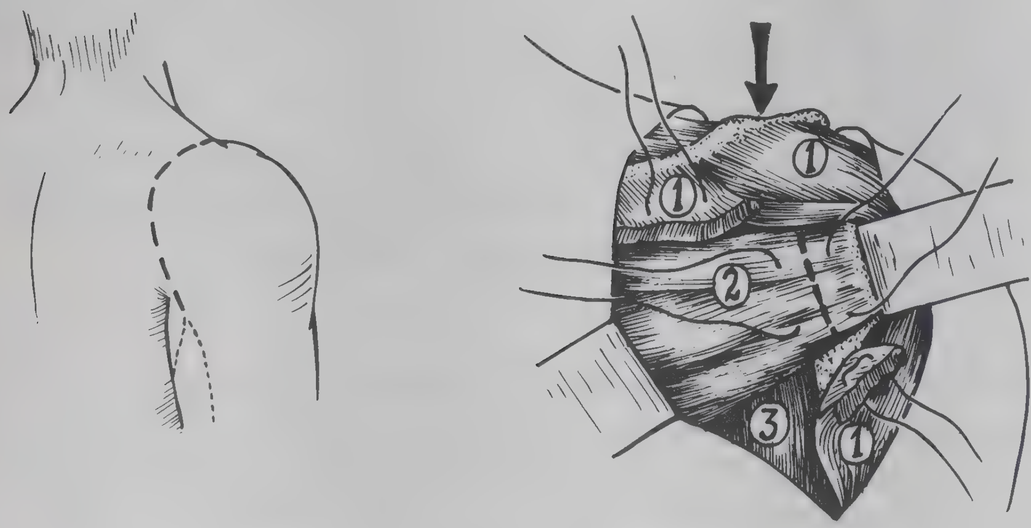
Closure: Repair the clavicle with steel wire through the drill-holes. Drain the compartments deep to the breast muscle, and repair the muscle by tying the stay sutures. Add interrupted mattress sutures.

8



8 Exploration of the shoulder joint – the standard anterior incision: The skin incision follows the border of the deltoid muscle. You may extend the incision across the acromion bone to the posterior side of the joint (ill. 9), and distally through the breast muscle to the medial or lateral side of the arm. (1): The fascia is split from the acromion downwards. The deltoid muscle is retracted to the lateral side. (2): Stay sutures are inserted, and the flexor muscles are cut close to the coracoid bone and retracted downwards. (3): The joint capsule is exposed by splitting the muscles in front of the joint. Control the small artery crossing the capsule, incise the capsule (dotted line) and enter the joint. Closure: Drain the compartments close to the joint (ill. 4). Close the joint capsule and the deep muscle layer (3) with close, interrupted sutures. Reattach the flexors (2) to the coracoid process with stay sutures.

9



9 The standard posterior incision: Start the skin incision 4-5 cm medial to the end of acromion, and turn it along the posterior border of the deltoid muscle towards the medial or lateral side of the arm. (1): The posterior part of the deltoid muscle is cut between stay sutures 2 cm from its acromion attachment. (2): The posterior rotator muscles of the shoulder are cut between stay sutures 2 cm from their humerus attachment (dotted line), and you look onto the joint capsule lateral to the elbow extensors (3).

Shoulder fractures

Fractures of the clavicle

Even compound clavicular fractures heal well. Explore the subclavian vessels in compound fractures; remove or trim protruding bone fragments to prevent vascular damage. Fractures of the lateral 2-3 cm of the clavicle are best managed with resection of the lateral part of the clavicle (ill. 3) provided the ligament between the clavicle and the coracoid process of scapula is not injured. We do not recommend the traditional figure-of-8 traction bandage for fractures of the clavicular shaft; if the patient is mobile, he should wear a broad arm sling with a cushion in the axilla; in bed the clavicular fracture is reduced by putting a pillow between the scapular bones. Effective analgesia is important to prevent lung complications.

Fractures of the scapula

They heal well. The main point is early mobilization under analgesia to avoid adhesions that may "freeze" the scapula to the chest wall.

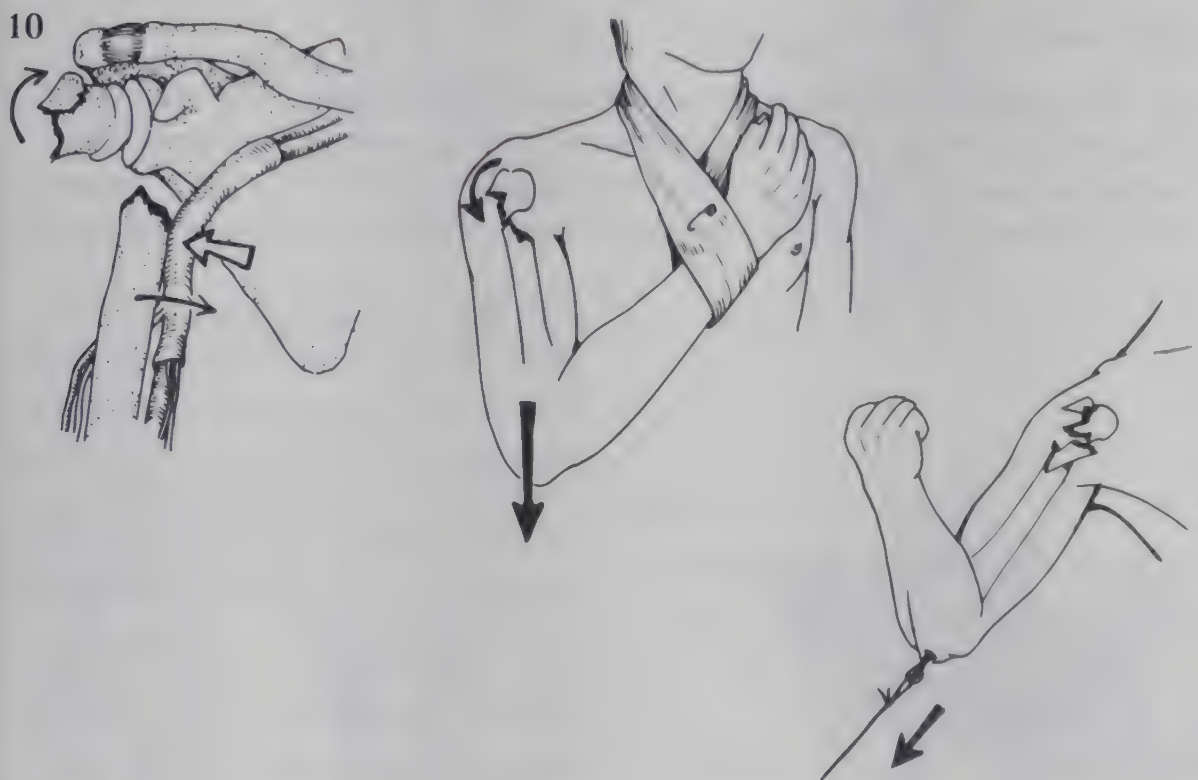
Fractures to the joint

The management of joint injuries in general: p. 217.

Muscle rotation flaps: p. 201.

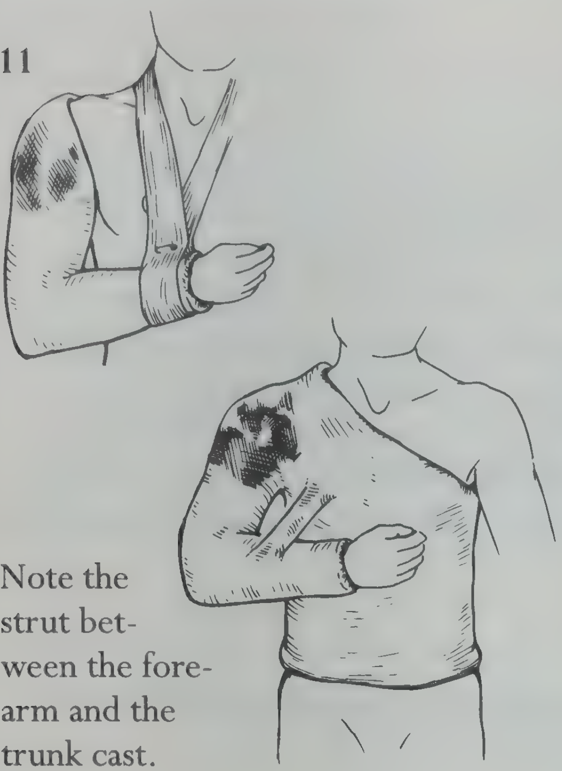
Reconstruct fractures of the glenoid to form a smooth joint surface. Fractures of the cartilage are trimmed with a knife. The patient with a glenoid fracture should start pendulum exercises within one week after the injury under effective analgesia. The exercises help reduce displaced fracture fragments. Fractures of the head of humerus heal well provided the fracture is covered by viable muscle. Try to save the head of humerus even in comminuted fractures. Replacement, resection arthroplasty or arthrodesis can be done later.

10



10 Fractures to the neck of humerus: The pull of the deltoid muscle will rotate the head fragment. Also the breast muscle will pull the shaft fragment in the medial direction. Manipulate the fracture with care, and watch the distal blood circulation: The axillary artery may be damaged. The neck fractures heal well provided they are well debrided and drained. Simple fractures are immobilized for 2-3 weeks in a "collar and cuff" bandage. Let the weight of the arm reduce the fracture by traction. If the fracture is displaced or comminuted, consider elbow traction with an olecranon eye screw.

11



Note the strut between the forearm and the trunk cast.

Amputation surgery in general: p. 237.

Extensive shoulder injury

11 Long-term Trueta plaster spica: The Trueta method of management is an alternative to primary amputation. An absolute condition for success with the Trueta method is very thorough early debridement. Note that the gauze drain should also enter the deep compartments of the shoulder (ill. 4). If the injury is distal to the joint, the plaster need not include the trunk. In major joint injuries the plaster spica should include the shoulder girdle, the trunk, and it should rest on the pelvic wings. Note that the shoulder is immobilized while one assistant continuously pulls the arm and the shoulder in slight flexion and abduction.

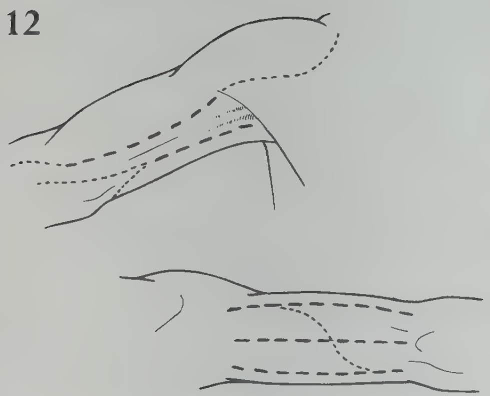
Arm amputation

The indication is not fractures or damage to the joint – they normally heal. Primary amputation should be considered in cases where there is both vascular and nerve injury – especially if there is also extensive loss of muscle, if the patient sustained protracted circulatory shock, and in old patients. The main points:

- Make a medial incision proximally from the level of amputation to explore the main vessels. Cut the nerves proximal in the axilla.
- Leave the exploratory incision open as a fasciotomy.
- Save every cm possible of the humerus – even a short humerus stump may wear a prosthesis.
- Leave the crushed head of humerus in site: It makes a better contour of the shoulder.
- If possible, save the deltoid and the posterior muscles to form a thick posterior flap.

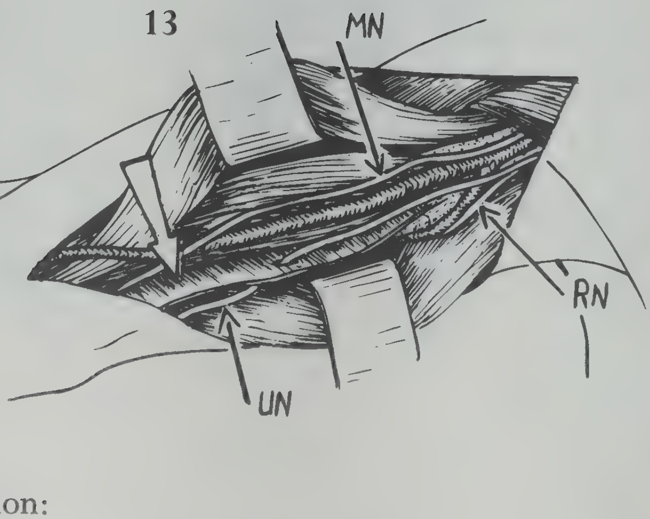
Exploration of arm injury

12



12 The standard exploratory incisions: The inlet and outlet wounds are extended into one of the standard incisions for exploration of the arm. The medial incision is not made directly over the artery and nerves, but 2 cm anterior or posterior to them. The standard dorsal incision is straight or S-shaped.

13



13 The medial exploratory incision gives access to both the anterior and posterior fascia compartment of the arm. Split the muscle fascia along the fibers and identify the main brachial artery together with the median nerve (MN). The deep brachial artery with the radial nerve (RN) penetrate the fascia septum proximal on the arm, and can be identified by blunt exploration into the posterior compartment. The ulnar nerve (UN) is located in both fascia compartments. **Notice:** The level of the deep artery is not constant – it may leave the main artery close to the shoulder joint, or at the mid-arm.

The posterior exploratory incision: see ill. 27.

Fasciotomy and drainage of the arm

Compartment syndrome and fasciotomy: p. 177.

Compartment syndrome with increased pressure under the muscle fascia is common in forearm injuries, but less common in arm injuries. Still we recommend fasciotomies of both the anterior and the posterior fascia compartment in major arm injuries. The fasciotomy can be done through a medial or lateral incision. Also drain compartments in high-energy injuries – even if the injury seems to affect one compartment only.

Vascular injury

The risk of thrombosis is generally high after reconstructions of the brachial artery. One reason is the poor soft tissue cover for the artery. Vascular reconstructions where the anastomosis is left exposed to air will certainly fail. In most cases, brachial artery injury with extensive loss of soft tissue necessitates primary amputation – unless muscle flaps can be mobilized to fill in the defect.

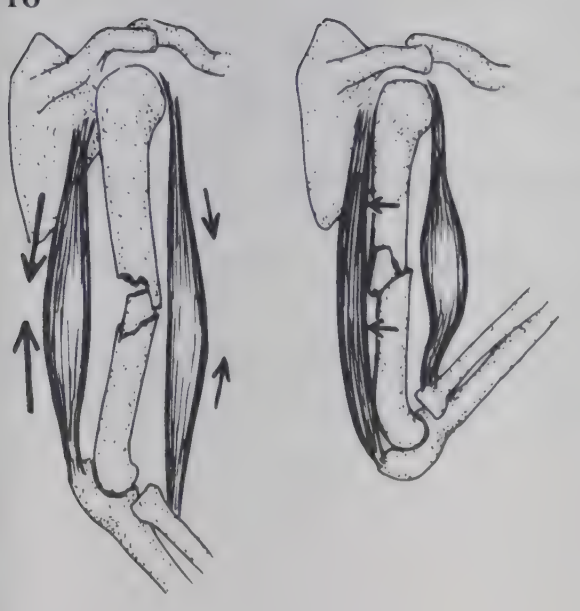
14

15

14 Local muscle flaps to cover vessels, nerves and fractures of the arm. The deltoid and triceps flaps: The deltoid muscle is split and brought forwards or backwards. The tendon and muscle belly of the triceps are split along the dotted line, released from the fascia septum (black arrow) by sharp dissection, and one half of the muscle displaced either laterally or medially.

15 The biceps flap: The tendon and aponeurosis are cut below at the elbow (dotted lines). The biceps belly (1) is released by blunt dissection from the brachial muscle (2).

16

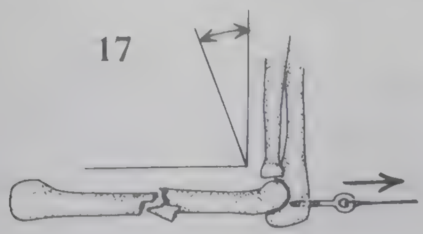


Open arm fractures

Humerus fractures heal well, provided they are covered with viable muscle. In comminuted fractures of the shaft, the radial nerve should be explored and special care taken to drain the hematoma that may form around the nerve inside the extensor muscle.

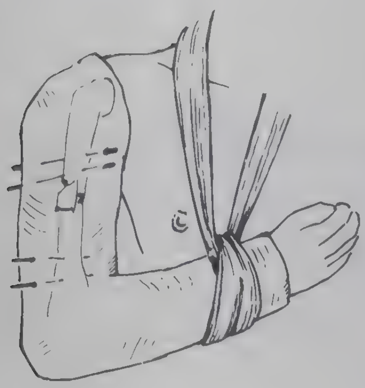
16 Prevent angulation of shaft fractures: The shaft fractures tend to be pulled into angulation by the strong extensor muscle, especially so if much of the flexor muscles are excised during the debridement. Use the extensor muscle as a splint: Immobilize the shaft fractures in an elbow flexion slightly more than 90 degrees (collar-and-cuff or plaster cast). In this position the extensor muscle is stretched and acts as a dynamic splint for the fracture.

17



17 Elbow (olecranon) traction: The method is rapid and well suited for multi-injury cases. Traction weights of 3-5 kg reduce most shaft fractures. Order careful elbow exercises during the traction period, and isometric forearm and hand exercises to prevent edema. Within 3-6 weeks when the wound is closed and the fracture "elastic", apply plaster cast (ill. 18).

18



18 External fixation: Fractures of the shaft of humerus are well suited for plaster-and-pin fixation. Watch the radial nerve!

19

19 The arm plaster cast: The inexperienced may apply the cast in two steps – first the arm part, then add the forearm part. A long slab from well above the acromion is fixed with circular turns. Note the traction on the fracture: Maintain constant traction until the cast is finished. Mold the plaster well (medial-lateral compression) to fit the arm contour. The cast should reach the acromion and fit the deltoid muscle snugly. The elbow should be in slight flexion and neutral position (no forearm rotation, the thumb pointing upwards) when the forearm part of the cast is applied. Mold the forearm cast well (ill. 51), and support the cast in a collar-and-cuff sling.

Low arm amputations

Extensive injuries are either managed with primary Trueta plaster or primary amputation is done. The main points of the amputation surgery:

Amputation surgery: p. 237.

- Design anterior-posterior flaps, or medial-lateral flaps depending on the wounds.
- Normally the medial and anterior flaps of the arm have the best blood supply: They can be rather long without turning necrotic.
- Extend the medial skin incision to explore the brachial artery proximal to the level of amputation. Then carry out fasciotomy of the two fascia compartments (ill. 13).
- Both flexor and extensor muscles retract when you cut them: Save all length possible of the muscle bellies.
- Ignore skin defects: You may cover them with split-skin grafts later, as the upper arm stump does not carry weight.
- At the time of closure: Split the muscle bellies on the flexor and extensor side to form four muscle bundles. Do myoplasty for better muscle control of the stump.

Myoplasty: p. 242.

Elbow injury

Surgical anatomy

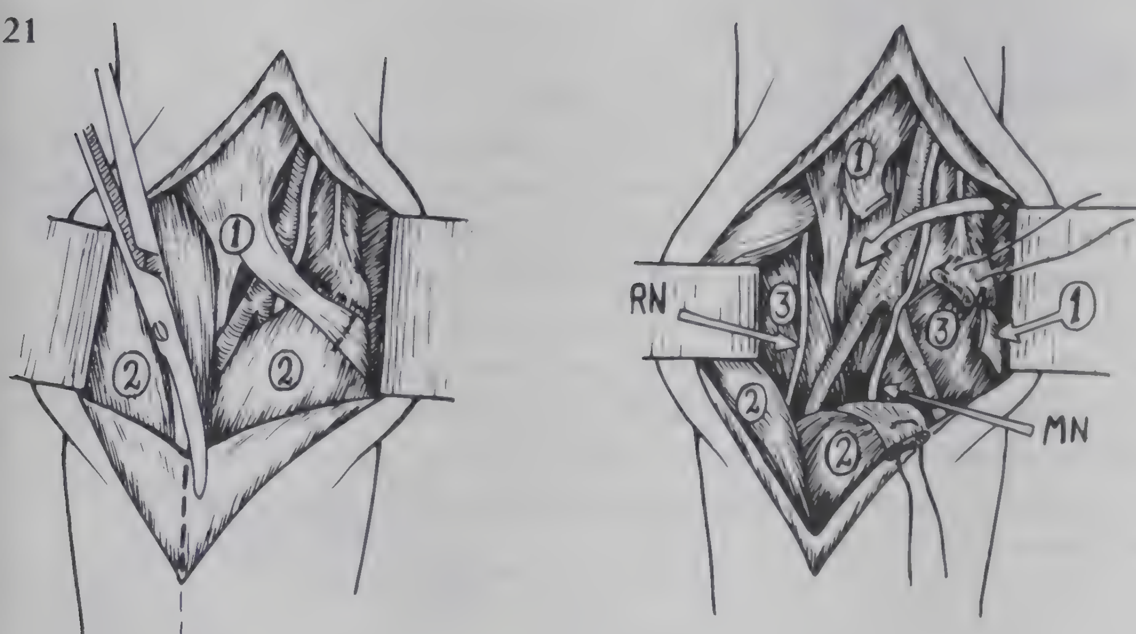
As the elbow area is well vascularized, soft tissue injuries and fractures heal well. The two main management problems:

- Hematoma and abscess formation: There is considerable effusion and bleeding from injuries at the elbow. Fluid and blood collect in several spaces and compartments close to the joint. Unless the deep compartments are explored and drained, the joint is at risk: Study the anatomy carefully.
- Nerve and vascular damage: The main vessels and nerves have poor soft tissue protection at the elbow area. Both the missile, the shock wave and bone fragments may cause combined vessel-nerve injury.

20

20 The vascular network at the elbow: Because of the rich network of collateral arteries, the debridement of the soft tissues may be limited. Ligature of the brachial artery at the elbow level in young patients will result in distal gangrene in one out of four patients – provided the collateral arteries are not damaged. If you consider ligating the brachial artery, note that the anterior radial collateral artery runs together with the radial nerve (RN). Loss of radial nerve function of the forearm/hand indicates damage to this collateral artery. The main ulnar collateral artery runs together with the ulnar nerve (UN) – signs of ulnar nerve injury also indicate damage to the ulnar collateral vessels.

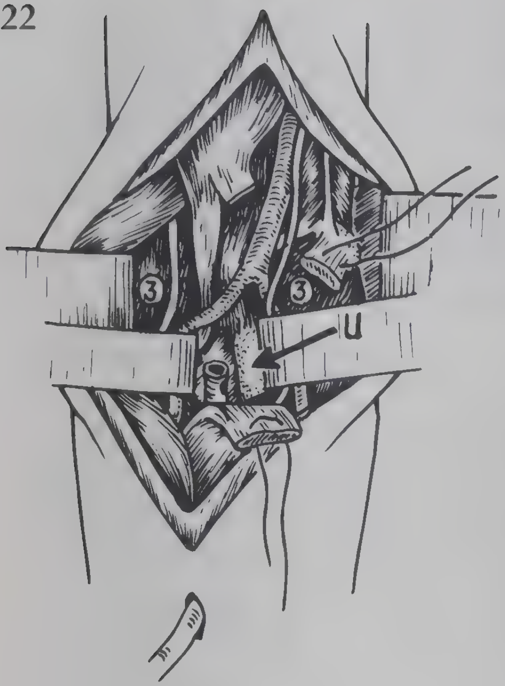
21



21 The volar compartments to be drained at the elbow – the superficial compartment: There are two separate fascia compartments on the volar side of the forearm. The superficial compartment contains the superficial set of hand flexor muscles, the radial artery, the radial nerve (RN), the ulnar artery and the median nerve (MN). The roof of the compartment consists of the strong superficial forearm fascia, the somewhat thinner deep fascia makes up the floor. To prevent compartment syndrome, a complete fasciotomy of the superficial forearm fascia (along the dotted line down to the wrist) should always be done in high-energy elbow injuries. The deep forearm fascia separates the superficial (2) and the deep (3) groups of forearm muscles. In extensive elbow injuries also

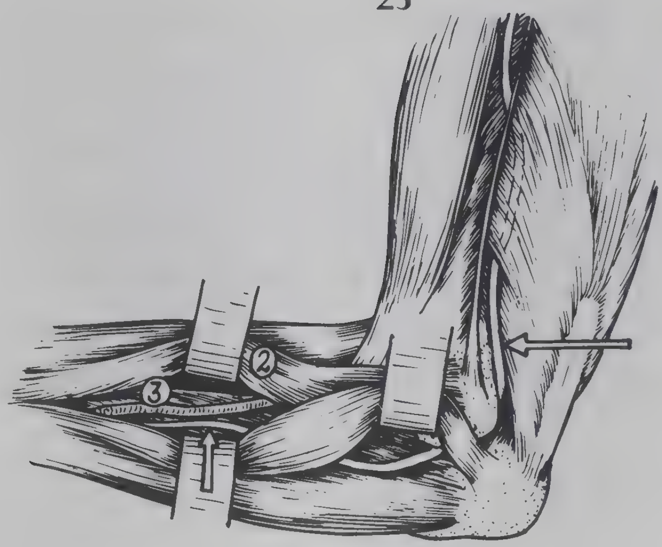
the deep fascia should be split and the deep compartment drained to prevent a deep compartment syndrome. To explore the deep compartment: Cut the biceps aponeurosis (1) along the dotted line. Insert stay sutures and cut the flexor muscles (2) close to their attachment to the medial epicondyle. By downwards retraction of the flexor muscles and lateral retraction of the extensors, you enter the space where the main arteries and nerves are located. Identify and retract them carefully and expose the deep fascia by blunt dissection.

22



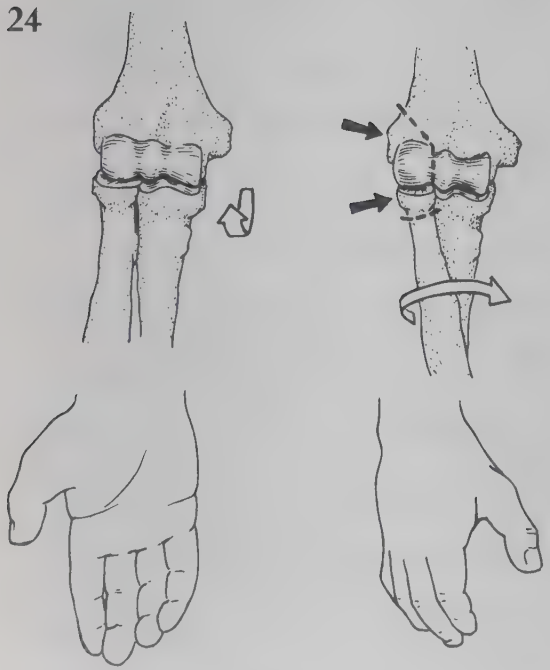
22 The deep volar compartment: Hematomas may also form under the deepest muscle groups (3) along the interosseous membrane between the ulnar (U) and radial bones. To reach this space, retract the radial artery to the radial side, the ulnar artery to the ulnar side. Insert a tube drain with side holes through a separate stab incision.

23



23 The ulnar nerve: Of the three main nerves at the elbow level, the ulnar nerve (arrows) is most vulnerable to injury. High-energy missile shock waves may stretch the nerve between the epicondyle and its crossing of the upper arm septum. Displaced bone fragments in low humerus fractures may tear the nerve. Poor padding of the elbow during protracted surgery may cause pressure damage to the nerve on the operating table. Below the elbow, the nerve is located close to the ulnar artery, well protected under the superficial flexor muscles (2).

24



24 The elbow joint consists of two joints

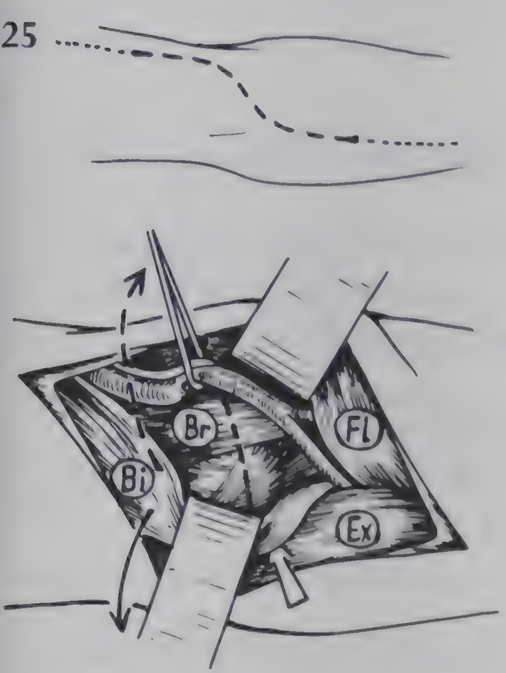
- Flexion-extension: The joint between the ulna and humerus is a hinge joint. Fractures of the medial humerus condyle may cause instability and block flexion-extension of the elbow. Take special care to preserve the medial condyle and reduce fractures in the medial part of the joint accurately.
- Rotation: The joint between radius and humerus is for rotation of the forearm. Forearm rotation is essential to good hand function, and every effort should be done to preserve maximum rotation in this joint. That is mainly a matter of early post-operative training – you may resect the lateral epicondyle of humerus as well as the head of the radius (black arrows), and rotation is still possible.

Exploration of elbow injury

Wide exploratory incisions!
As the anatomy is complex, no missile injury is like another. The shock wave may reach far from the wound track along one muscle bundle, leaving the other muscle bellies without injury. There may be extensive necrosis of the deep forearm compartment whereas the superficial muscles are without signs of injury. The missile shock wave may cross the joint: Especially in comminuted fractures, wide fasciotomies of both the forearm and upper arm should be done.

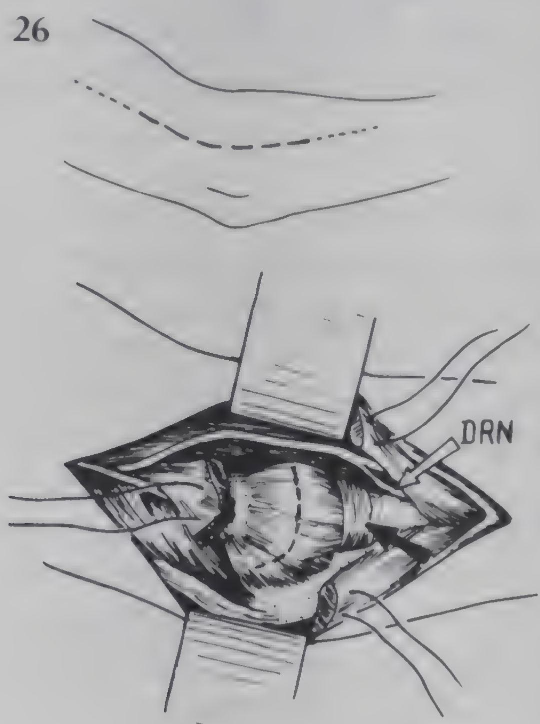
The upper arm fasciotomy: p. 490.
The forearm fasciotomy: p. 502.

25



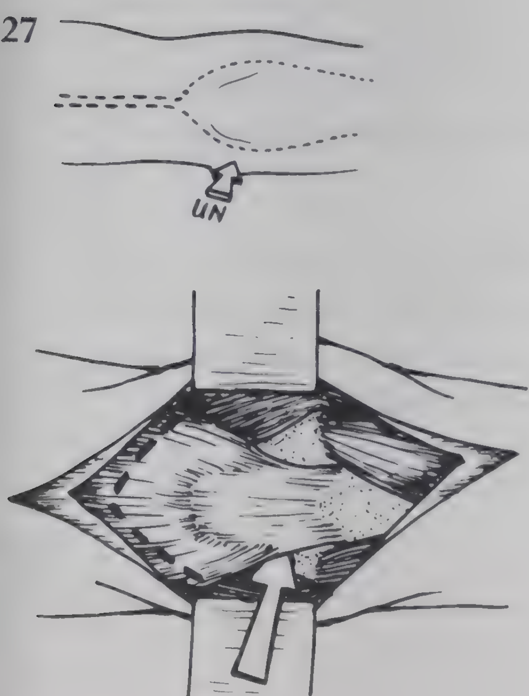
25 The standard exploratory incisions – the anterior incision: The missile wound track is extended into an S-shaped incision. Tie the superficial veins, split the aponeurosis of the biceps muscle and the superficial forearm fascia (ill. 42). You can now identify and control the brachial artery. Identify the median nerve, then retract the extensor muscles (Ex) and the biceps (Bi) to the lateral side, and the flexors (Fl) to the medial side. Split the brachial muscle (Br) and the joint capsule by a transverse incision (dotted line).

26



26 The lateral exploratory incision provides the easiest access to the elbow joint. The skin incision is 2 cm in front of the lateral epicondyle of the humerus. Split the extensor muscles along the fibers, insert stay sutures and cut the muscles sharply close to the attachment. **Notice:** Do not damage the deep branch of the radial nerve (DRN) with retractors; it is located deep inside the extensor muscles. Enter the joint through a transverse incision of the capsule (dotted line) without cutting the ring ligament around the neck of the radial bone (black arrow).

27



27 The posterior exploratory incision is used to expose fractures of the lower part of the humerus, and as counter-incision to explore and drain inlet-outlet missile injuries. The skin incision follows the posterior midline of the upper arm to the medial or the lateral side of the elbow bone (olecranon). Beware of the ulnar nerve (UN). To expose the distal part of humerus: Split the triceps muscle in the midline and release it from the bone by blunt and sharp dissection. To expose or enter the posterior part of the elbow joint: Cut the triceps muscle along the dotted line and deflect the distal part of the muscle to expose the joint.

Elbow fractures

The Trueta method of fracture management: p. 208.

Missile fractures – first things first

- Step one – soft tissue care: There is no time for elaborate fracture surgery during the first operation. Instead reduce the fracture roughly. Fracture fragments that may hurt main vessels and nerves are explored and reduced or resected under direct vision. Concentrate on debridement, fasciotomy and drainage. Apply Trueta plaster cast for 1-3 weeks.
- Step two – fracture care: Re-explore the soft tissues, redebride if necessary. Reduce and fix the fracture. Consider mobilizing soft tissue flaps to cover the fracture field (ill. 32-34).

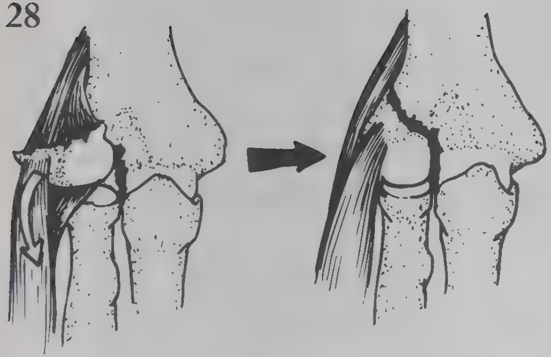
The management of joint injuries: p. 217.

Open joint injury

Do not miss a penetrating joint injury – do diagnostic needle puncture on suspicion (p. 223)

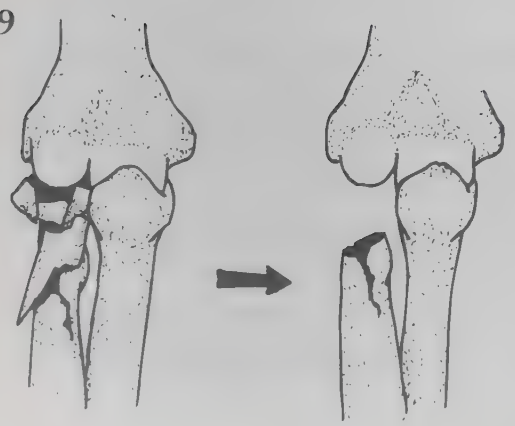
- Step one – avoid arthritis: Arrange continuous joint washout (normal saline with antibiotics). Close the joint – mobilize local soft tissue flaps if necessary. Drain the deep compartments close to the joint well. Delay the fracture management.
- Step two – manage the joint fracture: Re-explore the joint. Either reduce the fragments carefully and immobilize in plaster cast, or resect part of the joint (ill. 29 and 30). Start early exercises.

28



28 Fracture displacement due to muscular pull: The muscles working on the elbow joint may displace fractures of the epicondyles and olecranon (ill. 30). The degree of fragment rotation in epicondylar fractures is difficult to evaluate on the X-ray films. Interposition of muscle in the fracture makes closed reduction impossible: Explore the fracture; retract the interposed muscle to reduce the fracture. Resist the temptation to do primary Kirschner wire fixation of a fragment like this: The inevitable result will be osteomyelitis and a lost joint. In this case, flex the elbow to reduce the pull of the extensor muscles. Consider releasing the muscles partly from the fragment. Immobilize the fracture at about 100 degrees in flexion in the joint (standard casts, ill. 19). If the fragment again becomes displaced, leave it till the soft tissues have healed. Then reconstruct the joint and pin the fragment with Kirschner wire – or resect the fragment.

29

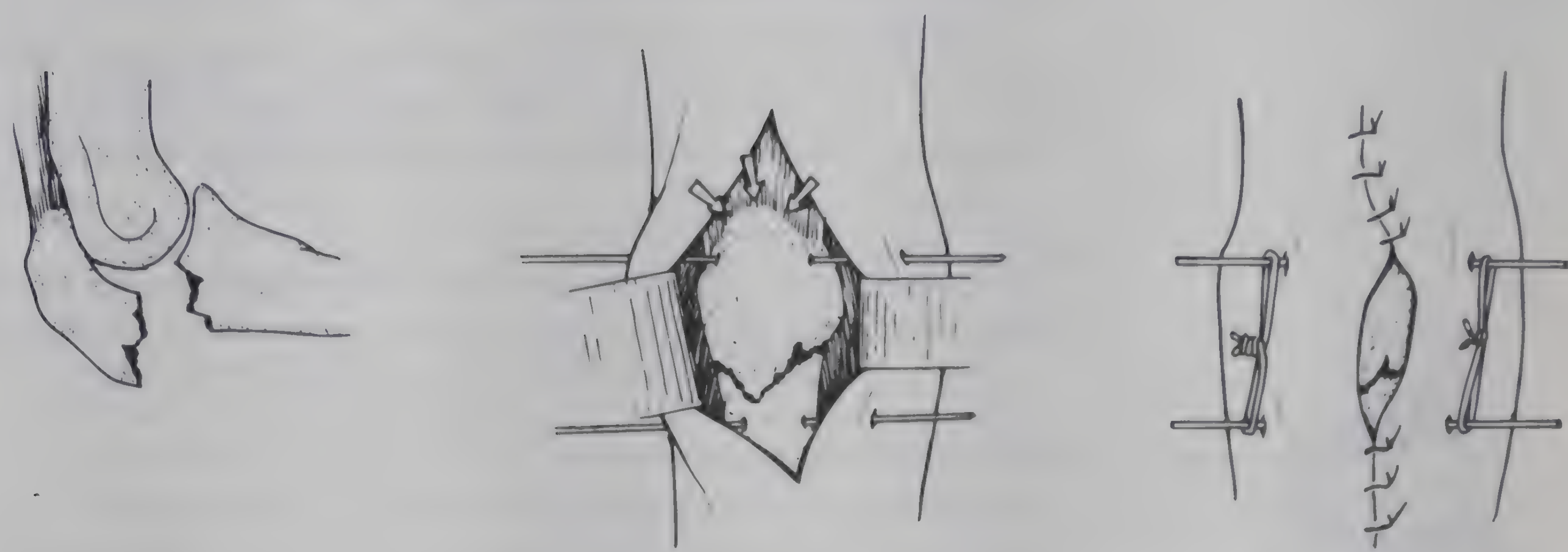


29 Primary resection of fragments in lateral elbow fractures: Try to preserve the medial, hinge part of the elbow joint. The lateral part of the elbow joint with the forearm rotation is less vulnerable to bone resections. Comminuted fractures of the head and neck of the radial bone are best managed by primary resection. Mobilize viable soft tissue to close the joint. Drain well. Start active rotation exercises within one week after surgery.

30

30 Olecranon fractures affect the hinge function of the elbow joint. Reduction is complicated by the strong triceps muscle pulling upon the fragments. A minor fragment of olecranon (less than one third of the joint surface) can be resected, and the flexion-extension stability still maintained. Some holes are drilled through the ulnar bone rim and the triceps tendon reinserted with strong silk sutures.

31



31 Olecranon fractures – major fragments: Resection of fragments including more than half of the joint blocks the flexion-extension and causes joint instability. The standard method of pinning across the fracture line cannot be used in open fractures. We recommend external fixation on double Kirschner wires: Expose the fracture and the triceps tendon through a posterior midline incision (ill. 27). Cut the central part of the triceps tendon close to the bone (arrows) to reduce the pull upon the fragment. Drill one heavy Kirschner wire through the skin and the fragment, and another through the ulna well outside the wound. Reduce the fracture with the elbow at not more than 45 degrees in flexion, and fix the fracture with steel wire bars around the Kirschner wires. A plaster splint, the elbow at a maximum of 45 degrees in flexion, is worn for 6-8 weeks.

Extensive elbow injury

Vascular injury

As a general guideline, the brachial artery should be reconstructed. Isolated injury to either the radial or the ulnar artery may be tied. The result depends on the patency of the collaterals (ill. 20), the venous drainage and the soft tissue state: Wide fasciotomies are essential. Vascular anastomosis must be covered with viable muscle: Mobilize local flaps (ill. 32-34) or distant flaps (the rectus flap, p. 201).

Limb-saving surgery

The extent of soft tissue injury – not the degree of joint damage – determines whether primary amputation should be done or not. An upper limb with a stiff elbow joint is still useful, and should be saved

Reasons to do primary amputation: p. 239.

- if the nerve sensory function is partly intact.
- if the motor function of the hand is mainly intact.
- if the elbow can be immobilized in enough flexion and supination for the palm of the hand to reach the mouth.

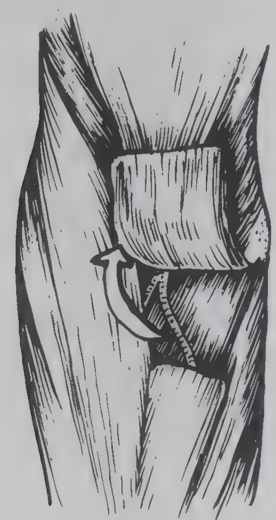
Limb-saving surgery is done stepwise. At each step, reassess the total limb and hand function and reconsider amputation:

- Step one – debridement and drainage: Excise all necrotic soft tissue without compromise. Drain the fasciotomies and all compartments with gauze, and apply a Trueta plaster cast with the elbow in minimum 90 degr. flexion for 2-3 weeks.
- Step two – reconstruction: If the limb is viable, mobilize muscle flaps to fill the soft tissue defects. Apply another Trueta cast for 2-3 weeks.
- Step three – closure: What has not healed spontaneously is covered by split-skin grafts.

32

32 **Local soft tissue flaps for extensive elbow injuries – the extensor flap:** To fill major defects, the groin or rectus flaps are recommended (p. 508 and 201). To cover minor soft tissue defects, local flaps may be used. Their advantage is that they do not immobilize the patients as do the distant flaps. Defects anterior as well as posterior to the joint may be covered by the extensor flap: The brachioradialis muscle and the wrist extensor are cut below the elbow (beware of the deep radial nerve, ill. 20 and 21) and mobilized by careful blunt and sharp dissection along the muscle fibers.

33



34

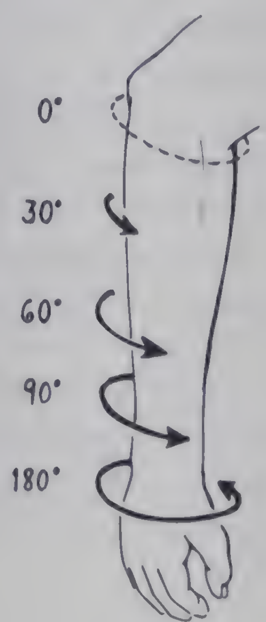
33 **The flexor flap:** The superficial flexors are cut and lifted off the deep forearm fascia. The flap may be mobilized in any direction.

34 **The triceps flap** supplements the below-joint flaps. Split out two thirds of the triceps muscle on either side, cut at its insertion into the olecranon, lift it off the humerus but maintain the proximal base.

Limb emergencies: p. 160.

Reasons to do primary amputation: p. 239.

The more distal the level of amputation, the better is the rotation of the forearm stump and the prosthesis.



Amputation after elbow injury

- Disarticulation through the elbow joint is done in emergencies only to free a trapped patient. Or in emergency surgery on an unstable multi-injury patient who cannot sustain protracted surgery. In all other cases, save a forearm stump.
- Save every cm possible of the forearm – even a short forearm stump may fit a prosthesis. Even without prosthesis the forearm "hook" is a useful tool.
- Use anterior-posterior or medial-lateral amputation flaps, depending on the actual injury.
- Do not let loss of skin determine the amputation level: split-skin grafts or rectus or groin flaps may close any forearm skin defect.
- Prevent flexion contracture of the elbow joint: Apply a well-molded primary plaster cast, the elbow joint in 45 degr. flexion, from the time of surgery until active exercises are started.

Forearm and hand injury

Surgical anatomy

The forearm and the hand – one functional unity
The forearm is the anatomical base of the hand function. Assess what will be the probable final hand function when you make up the management strategy for a forearm injury. The two main factors to consider:
- The function of the three main nerve-muscle units of the hand.
- The tendon-joint function of the forearm, wrist and hand.

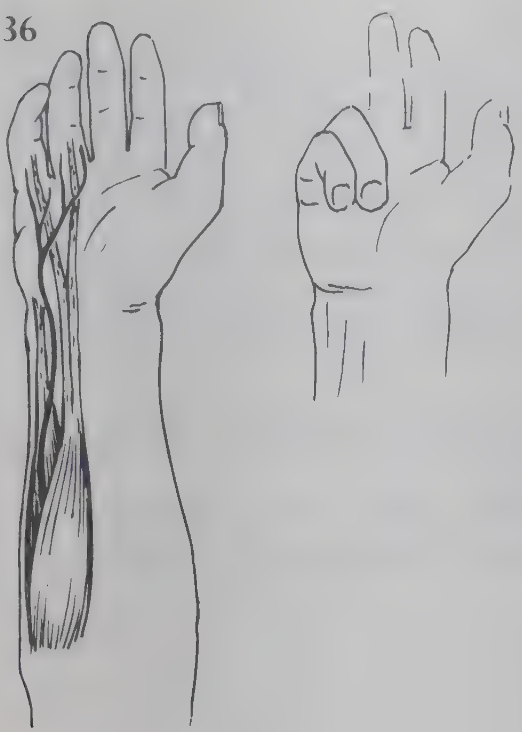
Assess the nerve-muscle function

From a functional point of view we separate the anatomy of the forearm and hand into three functional units defined by the three main nerves to the hand.

35

35 The functional unit of the median nerve – the radial grip: The median nerve controls the motor function of the radial flexor muscle of the wrist, the flexors of the 1st, 2nd and 3rd fingers and the sensory function of those fingers. The nerve runs down the forearm in company with the muscles it controls. The thumb-index pinch is a median nerve function.

36



36 The functional unit of the ulnar nerve – the ulnar grip: The ulnar nerve controls the motor function of the ulnar flexor muscle of the wrist, the ulnar flexors of the fingers (4th and 5th fingers), the interosseous muscles and the sensory function of the 4th and 5th fingers. The nerve runs down the forearm in company with the muscles it controls. Spreading the fingers and the ulnar part of the hand grip are the functions of the ulnar nerve.

37

37 The functional unit of the radial nerve – hand and finger extension: The deep branch of the radial nerve (ill. 20 and 21) controls the motor function of the posterior compartment of the forearm – the two wrist extensors and the extensors to all fingers. The superficial branch controls the sensory function on the extensor side of the fingers correspondingly. Also the branches of the radial nerve run together with the muscles they control.

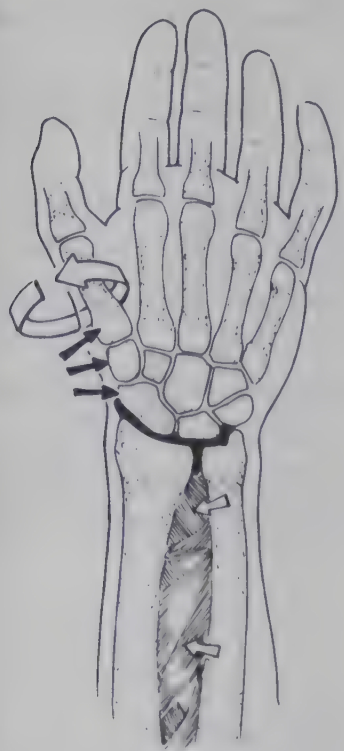
Bear these three functional groups in mind when you manage extensive injuries – some examples:

- Take special care to save the median nerve unit. It is the thumb-index pinch that makes the man's hand differ from that of the ape.
- Study the cooperation and balance between the three nerve units: You want to save the median nerve unit. Save the radial nerve unit also: What is the use of the flexor muscles if the extensors are paralysed, and the joint cannot be extended?
- Why save injured 4th and 5th fingers if the ulnar nerve function is lost? Without innervation the fingers are useless.

Assess the tendon-joint function

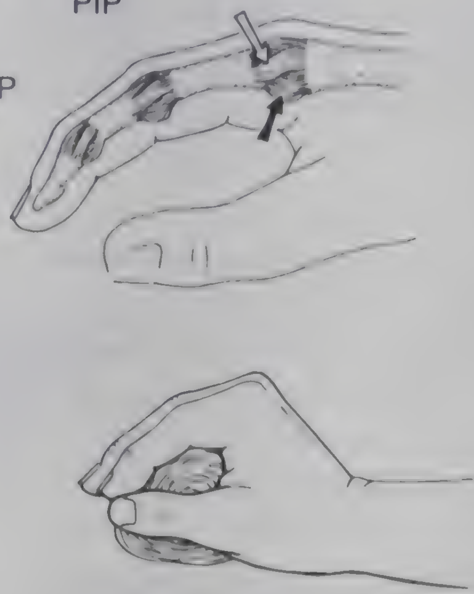
To save the nerve-muscle units is just half the job. The nerve-muscle units are working on tendons, ligaments and joints: The rest of the job is to reconstruct these structures by surgery, and restore their smooth function by post-operative training. When you have tested the three nerve-muscle units, assess the mechanical functions of the wrist and hand: To what extent will it be possible to maintain/reconstruct the tendons and joints? There is no rotation in the hand itself. The rotation is based in the joint between the radius and humerus (ill. 24) where the radius rotates around the axis of ulna. The higher up on the forearm an amputation is done – the greater the loss of the rotation.

38



38 The hand "ball joints": The wrist of the hand consists of several small joints. Take particular care to save the first (radial) ray of the small hand bones and joints (black arrows): The first ray carries the important rotation of the thumb. Without it, you cannot oppose the thumb to the other fingers, and the hand grip is more or less lost. **Notice:** The radius and ulna are connected by a strong ligamentous membrane (white arrows) that separates the forearm flexor compartment from the extensor compartment. Both compartments must be decompressed and drained separately in extensive forearm injuries.

39



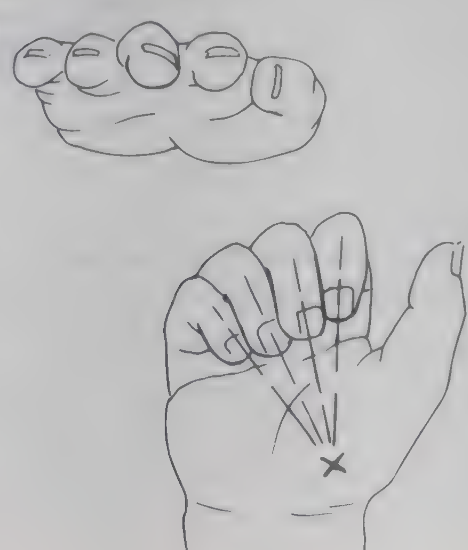
39 Incorrect immobilization is a common cause of hand and finger contractures. The MP joints of the fingers are stabilized by side ligaments (white arrow). The ligaments will contract and cause joint stiffness if the MCP joints are immobilized in extended position. The capsule of the PIP and DIP joints and the wrist and finger flexor tendons will also contract during immobilization. Thus the correct positions for immobilization:

- The wrist joint extended
- The MCP joints flexed
- The PIP and DIP joints extended

40

40 The tendon apparatus of the hand: There are two flexors and one extensor to each finger. On each finger are small muscles – the lumbricals (LU) and interosseous muscles (IO) – that connect the extensors and flexors. This complicated tendon apparatus is very sensitive to infection and contractures: Concentrate on good primary debridement, prevent infections, avoid prolonged immobilization, encourage early post-operative finger exercises. **The flexor tendons** run protected in sheaths deep in the palm. Infection inside the sheaths will spread rapidly and cause adhesions and stiff fingers. **As the extensor tendons** lie just beneath the skin, the main problem is soft tissue cover and scar contractures. Note the metacarpal fracture: The extensors may also be trapped inside the callus tissue – unless active and early finger exercises are done.

41



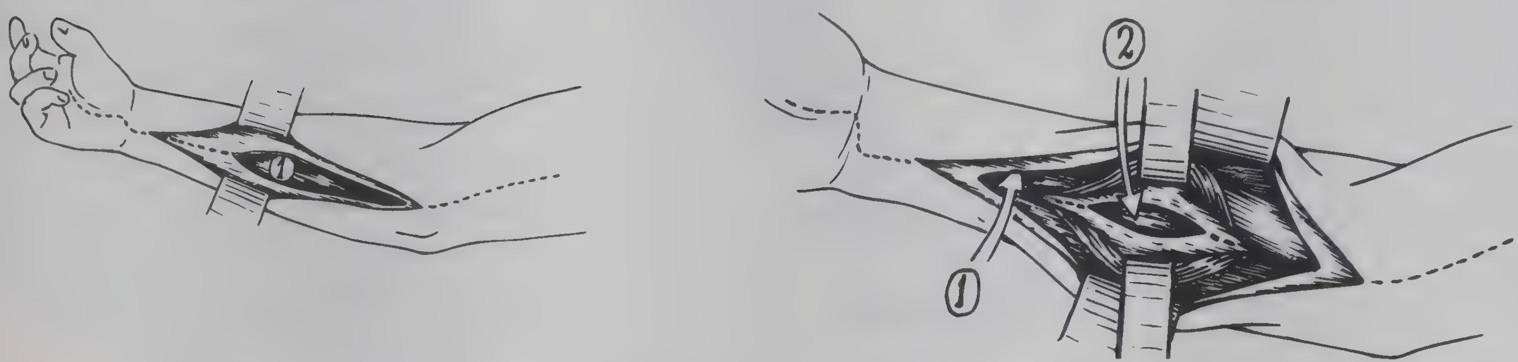
41 Finger fractures – rotation deformities: Control the alignment of the finger nails by looking at them end on. In this case a fracture of the 3rd finger has healed in malposition: When flexed, the 3rd finger will disturb the 4th finger function. Normally the flexed fingers should point to a common point at the wrist. If one of them does not, there is a finger fracture that needs reduction.

Prevent infections – drain the spaces and compartments of the forearm and hand

The hand is well vascularized. Still infections are common in penetrating hand injuries whether they are high- or low-energy injuries. The reasons:

- There are several compartments and spaces in the forearm and hand where hematomas may form. Unless the knowledge of anatomy is good and those spaces are systematically explored and drained, hematomas will form from which abscesses develop.
- Forearm decompression by fasciotomy is generally accepted as part of the primary management. But the fasciotomies are often incomplete: The deep compartments are not decompressed, and the palm of the hand is not decompressed. The result of poor venous drainage is increased risk of local necrosis and infection.

42

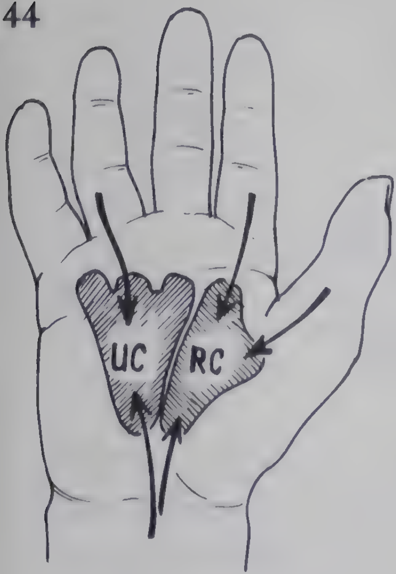


42 Fasciotomy of the forearm – the volar compartments: The superficial and the deep volar compartments are separated by the deep forearm fascia. Both compartments should be drained in high-energy injuries. Through a long volar midline skin incision the superficial forearm fascia is divided from the level of the elbow until the level of the wrist joint, and you look into the superficial flexor compartment (1). The muscle inside the superficial compartments is split by blunt dissection and retracted to each side: You can then see the deep forearm fascia. It is incised in the midline from the elbow to decompress the deep forearm compartment (2).

43

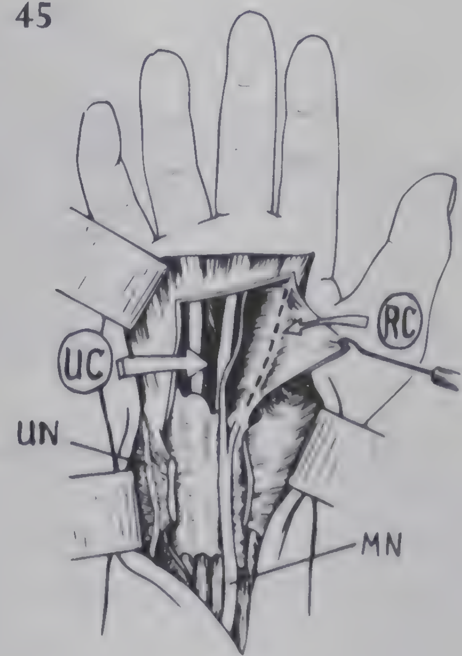
43 Fasciotomy of the forearm – the dorsal compartment and the fascia sheaths: Through a long dorsal midline skin incision the forearm fascia is split from the elbow to the wrist joint. Now you are looking into the common extensor compartment, (1). Inside this compartment, each muscle belly is surrounded by a separate fascia sheath. Edema inside the fascia sheaths may obstruct the local blood circulation. In high-energy injuries, also split the fascia surrounding each extensor muscle belly, (2).

44



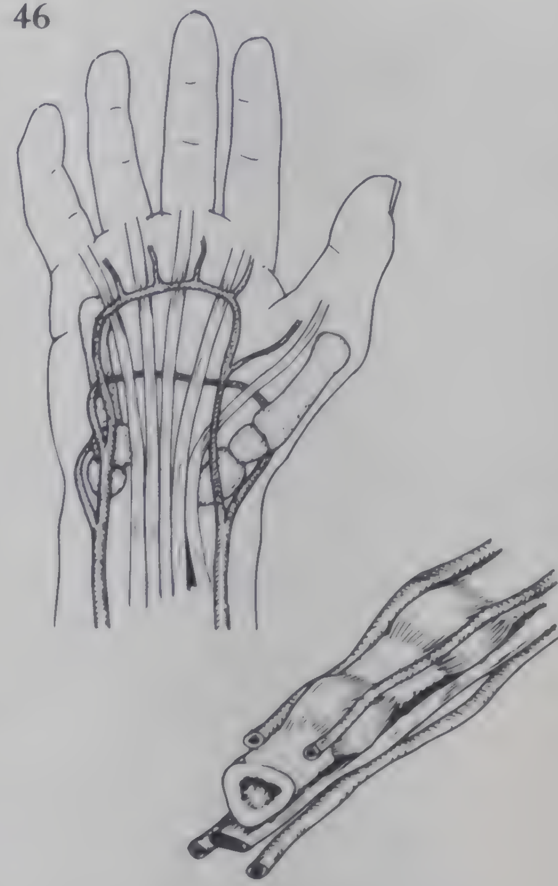
44 **The two volar compartments of the hand:** Under the thick palmar fascia are located the ulnar (UC) and the radial (RC) compartments of the hand. Through these compartments run the flexor tendons, the main nerves and vessels. Here blood and pus collect from both proximal and distal directions. The two compartments should be explored and drained as a routine in extensive hand injuries. Note that the compartments are separated by a wall – a double fasciotomy is thus necessary to decompress and drain completely.

45



45 **Fasciotomy of the hand:** The volar forearm fascia continues as the strong fascia of the palm. Split the fascia through a standard angular skin incision (ill. 49). Beware of the median nerve located immediately under the fascia. Work exactly in the midline at the wrist level so as not to damage the palmar branch of the ulnar nerve (UN). Open the ulnar compartment (UC) widely and explore the flexor tendon sheaths and the median nerve (MN). Also split the fascia over the flexor to the 2nd finger (dotted line) to enter the radial compartment (RC).

46



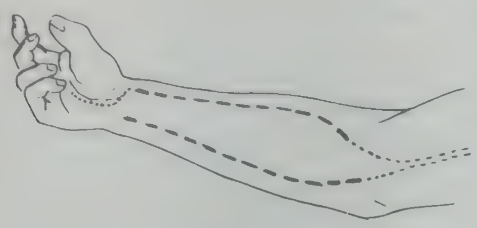
46 **The hand and finger blood supply:** There are two arches of arteries of the hand; one is located superficial, another deep to the flexor tendons. There are four arteries to each finger, the volar ones being the most important. In young persons one volar finger artery may carry enough blood to save the finger provided the venous drainage is good.

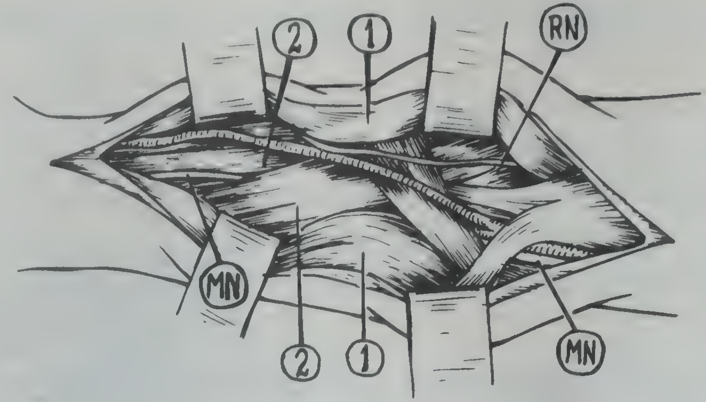
Exploration of forearm and hand injury

Fasciotomy! Elevation!
Limb injuries do not have first priority, and primary surgery is often delayed for hours. The delay may be critical to the limb blood perfusion, especially since the venous circulation may become obstructed. In extensive injuries:

- Do fasciotomy of the dorsal forearm compartment, the superficial volar forearm compartment and the hand immediately on admission (a five-minute procedure under ketamine anesthesia).
- Elevate the limb in a stockinette bandage (or metacarpal traction, ill. 53) – and leave it elevated until definitive surgery is done.

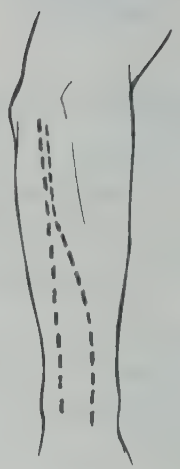
47





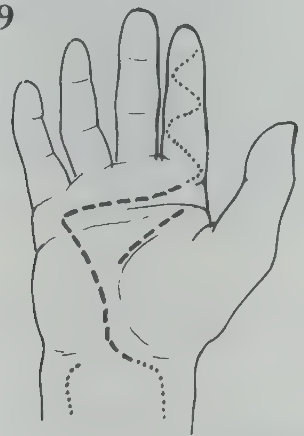
47 The volar exploratory incisions: The wound is extended to one of the standard incision for exploration. Use the volar incision to explore the main vessels and nerves. For fracture exploration, use the dorsal exploratory incision. Note that the incisions should cross the creases at the wrist and hand obliquely to avoid excessive scarring. The incisions are done on the ulnar or radial side depending on the injury. Do not hesitate to use two parallel longitudinal incisions to explore completely. Ligate the superficial veins, split the superficial fascia and retract the superficial flexor muscles (1) to expose the radial (RN) and median nerves (MN). To explore the mid-portion of the median nerve, you have to cut the superficial flexors just distal to their epicondylar attachment (ill 21). Split the deep flexors (2) to reach the ulnar bone and the interosseous membrane.

48



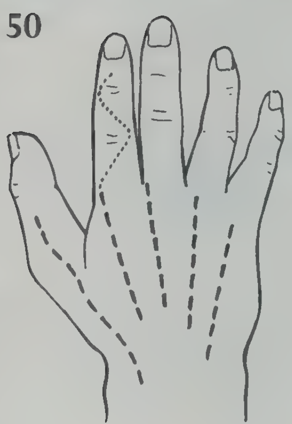
48 The dorsal exploratory incisions: Incise the skin just radial to the ulna. Release the extensor muscles from the ulna with a chisel, and retract them to expose the ulna, radius and the interosseous membrane.

49



49 Exploration of the palm: The angulated palmar incision may be extended to Z-incisions of the fingers. Exploration of the palm: ill. 45. By careful sharp dissection on the fingers, the skin with subcutaneous fat is lifted off the flexor sheaths. Do not damage the volar arteries and nerves (ill. 46).

50



50 Exploration of the back of the hand: Several longitudinal incisions rather than one transverse incision should be used for dorsal exploration. The incision may be extended to finger Z-incision.

Vascular injury

Vascular surgery: p. 185.

- Beware of the risk of intimal injuries of the brachial artery close to the elbow: Do arteriotomy on suspicion.
- Reconstructions of the radial or ulnar artery are seldom indicated: Tie one artery if the other is undamaged. If both arteries are torn, normally two or more main nerves are also damaged – this indicates primary amputation.
- Vascular reconstructions at the hand and fingers have no place in wartime surgery.

Management of nerve injury: p. 231.

Tendon injury

Explore and identify all tendon injuries at the time of primary surgery – which tendons are injured, at which level. Report exactly in the Patient Chart. Cut extensor tendons will not retract, cut flexor tendons will: Leave the proximal stumps of the tendons in the retracted position.

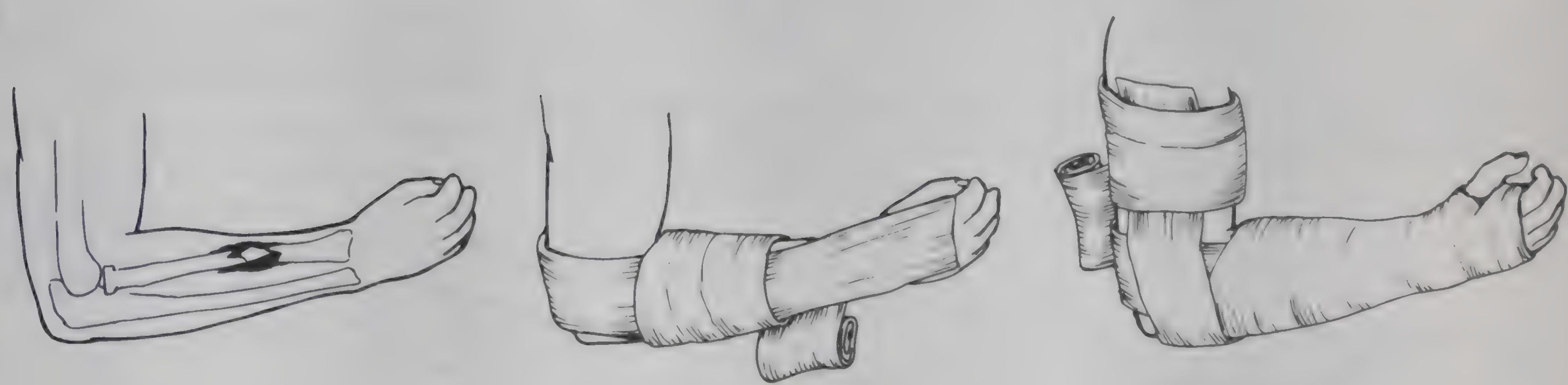
Fractures of the forearm and hand

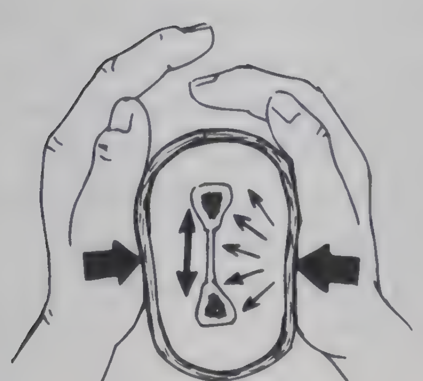
Open forearm fractures – the main points of management

- Do the exploration and debridement under traction as that makes the identification and dissection easier.
- Use wide exploratory incisions: The shock wave of high-energy injuries may reach areas far from the wound track.
- In particular explore the muscles close to the fracture: The deep compartment may be completely necrotic even if the superficial muscles show no signs of injury.
- If the soft tissues are well cared for, the fracture itself normally heals well: The bone debridement should be moderate. Major bone fragments without soft tissue attachment may be washed and realigned in the fracture field as bone grafts – provided the soft tissue cover is good.
- The exudation from deep forearm wounds is considerable: Both deep and superficial spaces must be well drained. We recommend the Trueta plaster method both for drainage and immobilization of open forearm fractures.

The Trueta method: p. 182 and 208.

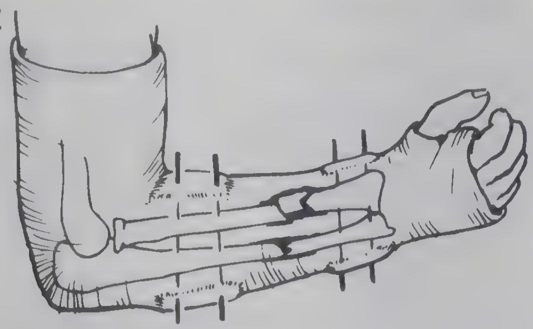
51





51 Plaster cast for forearm fractures: This radius fracture is relatively stable as the undamaged ulna acts as an "internal splint". The wrist joint is included in standard forearm casts. The plaster is applied under continuous manual traction until the cast has set. Mold the forearm part of the cast by volar-dorsal compression: Increased soft tissue pressure and the traction from the interosseous membrane will help stabilize the fracture. **Notice:** For the first few days after the injury, split the cast from the wrist to the axilla to prevent venous obstruction.

52



52 Plaster cast with pinning for unstable forearm fractures: Fractures of both the ulna and the radius are unstable, especially if the fracture is comminuted. Pin the upper and lower main fragments with double Kirschner wires and apply a standard forearm cast for external fixation (for details: p. 209).

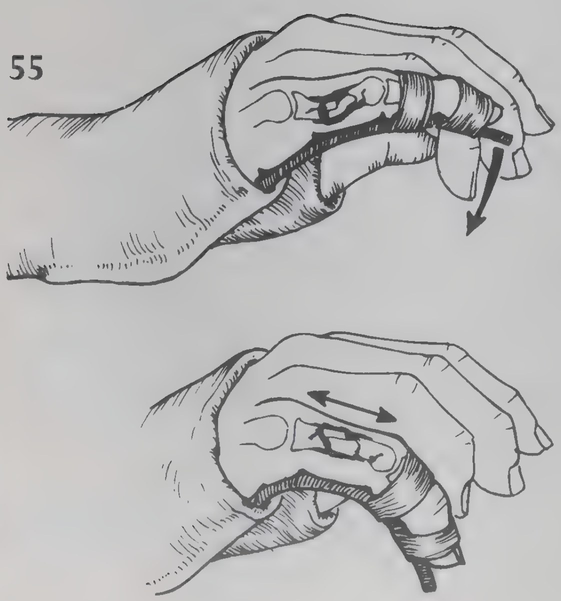
53

53 Metacarpal traction for comminuted forearm fractures: Traction has some advantages in extensive forearm injuries: It is simple, allows effective elevation and free finger movements, and allows monitoring of the wounds and circulation. The pin is drilled through the neck of the 2nd and 3rd metacarpal bones; compress the hand side-to-side to raise the two metacarpals. A counter-traction of 1-3 kg is applied on the upper arm. When the fracture has entered the callus stage (within 3-4 weeks), a plaster cast is applied: Do not remove the pin, but include it in the plaster and apply the plaster cast under traction. Thus the pin helps maintain traction on the fracture also inside the cast.

54

54 Bone resection in comminuted fractures: Make every effort to save the hinge joint of the elbow (circle) and the radial part of the wrist joint (circle). You may resect bone fragments of compound fractures of the upper radius and lower ulna affecting the joints (shaded parts) – and still maintain a reasonable function and stability of those joints. You may do the bone resection during the primary surgery, or later on. The strategy mainly depends on the primary soft tissue management: If you are unable to get soft tissue cover for the important parts of the joint, better do primary bone resection.

55



55 Plaster with traction for finger fractures: Comminuted fractures of the metacarpal bones and fingers tend to overlap or angulate. Traction should be applied at the time of primary surgery: A soft metal splint is fixed inside the cast with circular turns of plaster. The actual finger is fixed to the splint in an extended position by adhesive plaster (or a strong silk suture through the edge of the nail tied to the splint). The splint with the finger is flexed to exert traction on the finger. **Notice:** Look at the nail bed – is there any rotation deformity (p. 199)?

Extensive hand injury

Two step-surgery

- Be conservative during the first operation. Explore the injury well. Debride tissues definitely necrotic, but leave possibly viable structures for the second-look operation. Decompress the forearm and palm through wide fasciotomies. Drain the volar compartments of the hand. Apply massive compressive dressing from the hand to the elbow, elevate the limb, and start active finger motions under analgesia.
- Re-explore the injury under anesthesia after 24 - 48 hours. By then it will be clear which structures are necrotic and which are viable. Now do the definitive debridement, and plan the reconstruction of the hand.

The basic principles of primary management

- Concentrate on the radial part of the hand: Save every cm possible of the thumb and index finger.
- No ligatures – control bleeding by compression. Save all viable skin and soft tissue for the reconstruction.
- Do not leave vessels, nerves, tendons or joints open: Cover with saline-wet gauze until the second-look operation. Then mobilize local or distant soft tissue flaps to protect these structures.
- Do not close incisions and wounds under tension: Deep and tight sutures will obstruct the micro-circulation.
- Tendons and nerves are reconstructed when the soft tissues have completely healed without infection 2-6 months after the injury.
- Maintain the joint function: A schedule for post-operative active and passive joint exercises is an essential part of the surgery.
- Analgesia: Do not let pain prevent early exercises.

Soft tissue flaps: p. 200.

Non-traumatic techniques in surgery: p. 164.

56

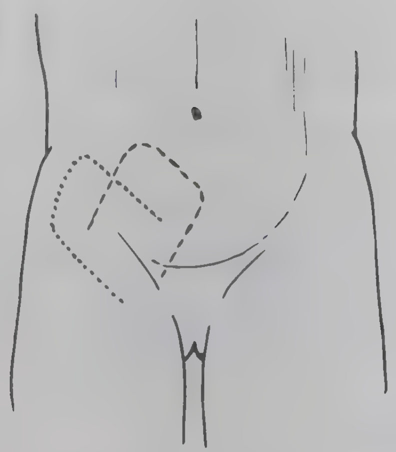
56 Watch this area: Flexor tendons injured in the shaded area are particularly difficult to reconstruct. Take particular care to prevent hematomas and infection in this area of the hand.

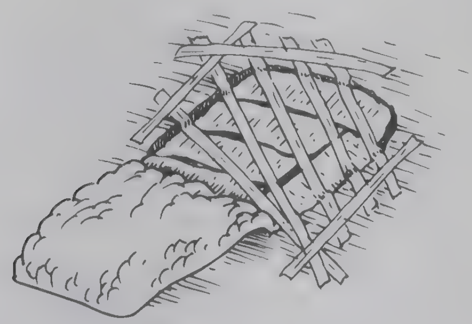
57

57 Tunnel flap for the finger: The tunnel flap is a safe and rapid method to cover stripped tendons and bone; you may use it at the time of primary surgery, or delay it until there are healthy granulations in the wound. A bridge of skin with some subcutaneous tissue is raised from the forearm, chest or abdomen. The skin proximal and distal to the tunnel is undermined along the fascia, and the defect inside the tunnel is closed by sutures. The finger is embedded in the

tunnel for 10-12 days, then one edge of the flap is cut (dotted line), trimmed and sutured to the finger wound. After 5-10 more days the other edge of the flap is cut, trimmed and sutured to the finger.

58





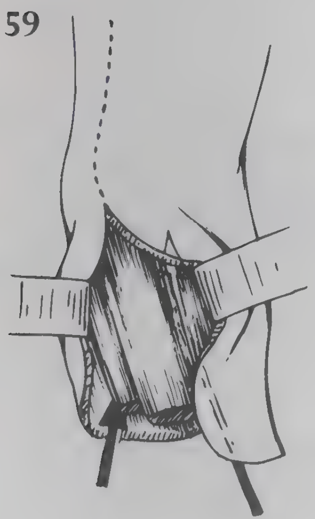
58 The groin flap is useful in cases with extensive loss of soft tissue in the palm or at the back of the hand. The flap is designed according to the site and size of the injury. **Notice:** The venous drainage from the flap is most important. Watch the subcutaneous veins when you raise the flap. The ratio of the flap length : flap base should not exceed 1.5:1. The flap is raised by sharp dissection (along the abdominal fascia in slim patients), the base thicker than the free end. The groin defect is covered with split-skin grafts. The flap is trimmed and sutured to the wound edges. Pad the area well, and fix the injured arm to the groin by adhesive plaster or external fixation apparatus. Within 10-12 days the flap should take its blood supply from the hand: Test by clamping the flap base, and study the circulation at the flap end. If the circulation after clamping is still good, split the flap at the base, trim it and suture it to the hand wound.

Amputations at the forearm and hand

Amputation surgery: p. 237.

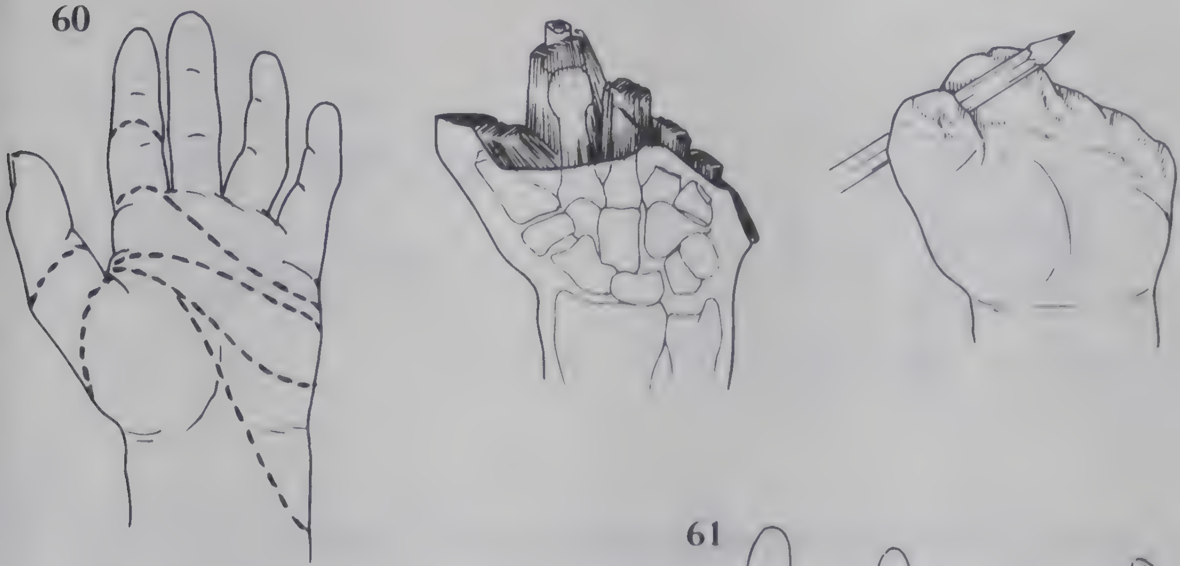
The "ideal" length is the maximum length
Do not cut the bone to fit the length of the soft tissue flaps: Better mobilize soft tissue flaps to cover the bone stump.

59



59 Decompress and drain the forearm stump: Raise volar-dorsal flaps, the volar flap has the best circulation and can be considerably longer than the dorsal one. Extend the lateral incisions as fasciotomies. Explore all muscle bellies proximal to the amputation level. The soft tissue padding of the forearm stump is poor, and all main nerves should be identified and cut well above the amputation level. Drain the spaces between the muscle by dry fluffy gauze, and apply a Trueta plaster with the elbow in 45 degrees flexion. The plaster will prevent elbow flexion contracture, prevent edema of the stump and provide excellent drainage. You may fix some sort of a hook inside the plaster, and encourage the patient to start using the stump hook the first day after surgery (IPOPF: p. 242). After 5-7 days the plaster is removed and the stump re-explored: Split the extensor and flexor groups and do myoplastic closure (p. 242). Close the lateral incisions, but leave the fascia incision open. Drain the volar and dorsal compartments separately. Trim and suture the skin flaps. Apply a slightly compressive dressing.

60



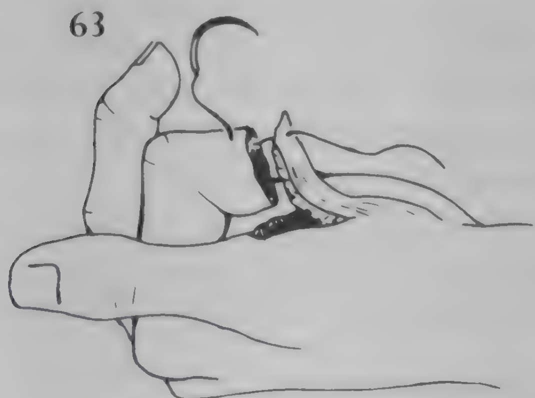
60 Amputations at the hand: The dotted lines represent amputation levels. The radial part of the hand is most important. You may save 1-2 cm of the stump length if you cover the stripped bone end with a full thickness skin flap (tunnel flap or groin flap). The 2 cm saved may be the difference between a grip function – or none. See also p. 256.

61

61 Ray amputations of the hand: Amputations close to the MP joint leave an open space between the fingers that impairs the hand function. Ray amputation gives a more functional hand: Make a dorsal incision and expose the metacarpal bone by blunt/sharp dissection. Cut it obliquely close to its base. Leave the incision open with gauze drainage. After 5-7 days the wound is re-explored, trimmed and closed.

62

63



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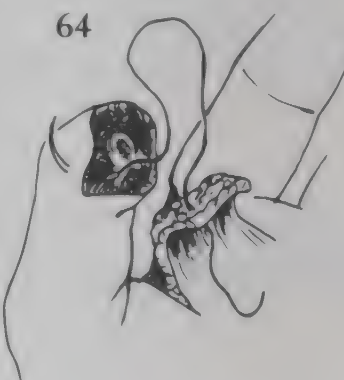
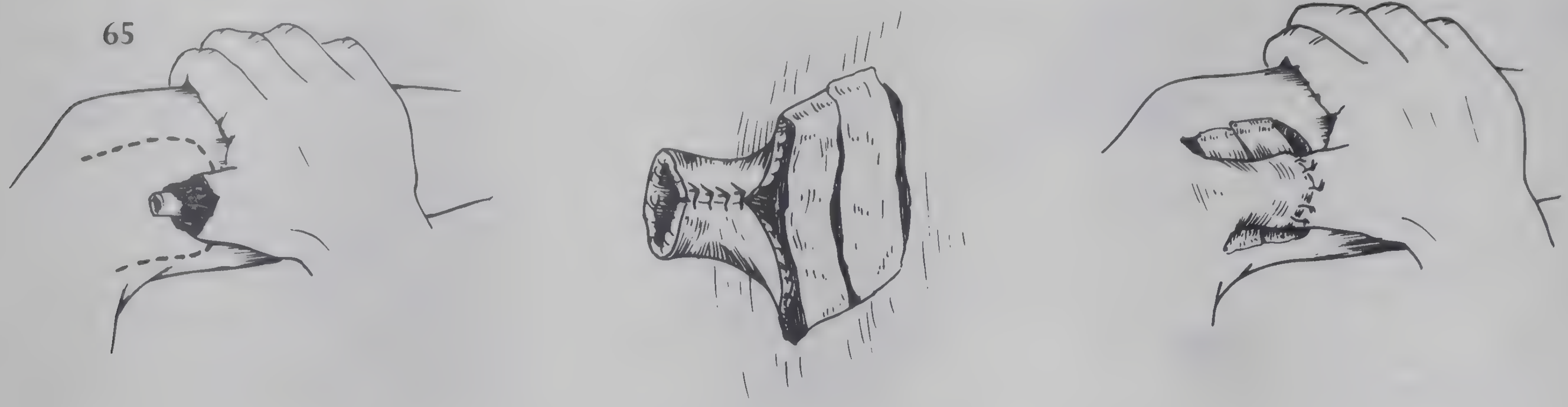


62 Sliding grafts save length! The skin viability determines the length of the bone stump. Try to save at least 1 cm of the bone distal to a finger joint, it will serve as a useful "hook". Design long volar flaps: The volar flap carries the main sensory function and the best blood supply. Better than cutting the bone to approximate the skin flaps, raise vascularized volar and dorsal finger flaps: Dissect carefully so as not to damage the main arteries and nerves.

63 Thenar flap for the index finger: The flap is raised along the muscle fascia of thenar. The donor bed is closed by sutures. The flap is trimmed and sutured to the index stump. Pad well and fix the index under flexion with adhesive tape. Test the circulation of the flap graft after 10-12 days (clamp the base): If the flap takes its blood supply from the finger, cut and trim the flap and close the amputation.

64 Palmar flap for the thumb: The flap is raised along the palmar fascia.

65



65 Tube flap for the stripped finger: For an adult thumb, the flap should be 9 cm broad. It is raised from the forearm, chest or abdomen. A tube is formed to fit the amputation stump. Note that the tube flap will swell during the early days after surgery: Design the tube wide enough to take that swelling.

Disarticulation

Disarticulation through the wrist joint or MCP joints is an emergency procedure. In hand and finger injuries it should be reserved for the release of trapped persons and during emergencies. In most cases it is possible to save at least parts of the hand or the finger.

Complications of injury and surgery

Complications of plaster management

We recommend the use of plaster casts for primary management of extensive upper limb injuries. But the plaster cast management may be a balance on the knife's edge: On the one hand the cast prevents soft tissue edema after injury and surgery. On the other hand it may cause a compartment problem and obstruct the blood circulation.

Reflex dystrophy – preventive measures and management: p. 206.

Reflex dystrophy is not uncommon after plaster cast management in upper limb injuries. Prevent that serious complication by splitting the cast, and carefully instructing the patient regarding the signs of alarm.

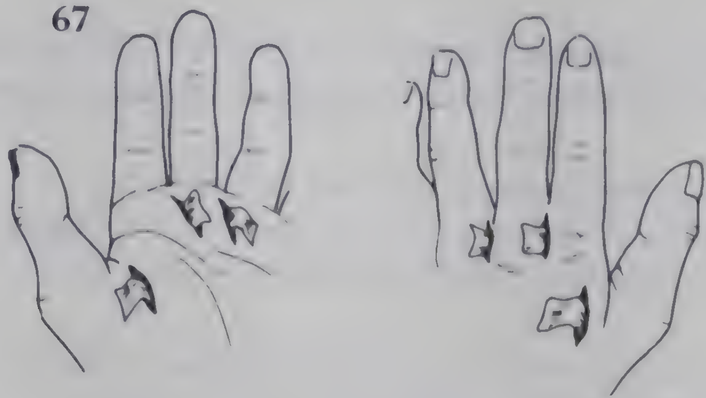
Soft tissue infection

The reason is poor primary debridement and poor drainage. Re-explore without delay the spaces and compartments where fluid normally collects: Wash out hematomas and abscesses with soap and saline. Complete the debridement. Consider fasciotomy if the limb or finger is swollen. Dress with saline-gauze twice a day.

66

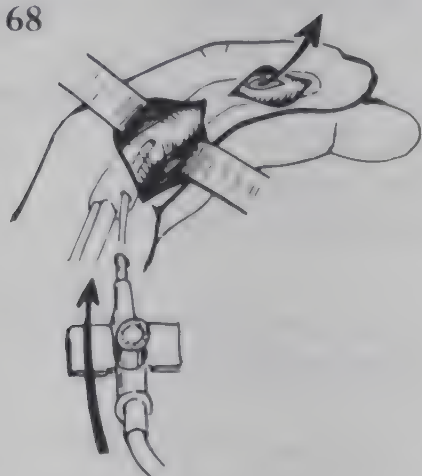
66 Deep infection of the palm – do not miss the diagnosis: The symptoms may be moderate – increased skin temperature and some restriction of the flexor function of fingers may be the only signs of infected palmar compartments. As the ulnar and radial compartments are separated, the abscess may be located in one of them only. Infection of the fingers or wrist may spread into the palm along the flexor tendon sheaths. Open the palmar space by the standard incision (ill. 47); explore both compartments and evacuate the abscess. Give continuous washing of the palmar space with antibiotic-saline solution through an infusion set with side holes.

67



67 Counter-drain the palm: Drain infected soft tissues before the palmar abscess develops. Through small stab incisions of the volar and dorsal skin, tunnels through the soft tissues between the metacarpal bones are made using forceps to pull gauze through the incisions.

68



68 Draining the flexor sheath: Explore a swollen and painful finger without delay. The reason is probably a missed injury, a tiny shrapnel etc. Infection inside or around the flexor sheath will cause a stiff finger unless the sheath is drained at an early stage. Open the sheath through a short lateral incision. Wash out the infection, and insert an i.v. plastic tube for continuous antibiotic washing for 1-2 days.

Arthritis and osteomyelitis

Diagnostic puncture of joints: p. 223.

The management is immediate surgery – antibiotics are supportive but cannot control the infection.

- Remove all bone fragments without soft tissue attachment.
- The most common reason of infection is poor soft tissue perfusion at the joint/the fracture: At the primary surgery, the surgeon tried to save what was not possible to save. Now resect all non-viable soft tissue and mobilize a well-circulated soft tissue flap to close the joint/the fracture.
- Or do amputation.

Management of arthritis: p. 223.

The bacterial pattern: p. 649-651.

Scarring and contracture

In some populations keloid formation is common: p. 251.

Soft tissue scars always contract, the result may be joint deformities. The treatment is surgery: Excise the scar and graft the defect before joint capsule, ligaments and tendons also contract. If the joint is already contracted, release it by tenotomy (p. 480).

Points to note – Chapter 39

Of all casualties managed at forward clinics, four out of ten are lower limb injuries; better study the complete chapter carefully.

Study the anatomy sections to know
- the standard incisions for exploration and debridement
- the deep spaces that should be drained

Specially note the exact localization of main nerves and arteries
- to avoid accidental nerve injury during surgery
- to be able to identify and control bleeding arteries: p. 120

Learn to do complete fasciotomies
- of the thigh: p. 522
- of the lower leg: p. 543
- of the foot: p. 544

Note the particular problems with injuries to the lateral lower leg compartment: p. 539-540

Note the particular problems with high-energy fractures of the calcaneus and talus: p. 547

39 Lower limb injury

Preparations for surgery

Instruments and surgical sets: p. 58.

Surgical equipment
- General debridement set
- Bone nibbler, chisel, Gigli saw
- Drill, Steinmann pins, Kirschner wires, eye screws, soft steel wire
- Plaster of Paris (rolls of 10 cm and 15 cm)
- If available: external fixation set
- If available: materials for orthosis application
- Instruments for vascular surgery: p. 59
- Suture materials: p. 60

A case for emergency surgery?
Associated injuries of the main arteries of abdomen and pelvis may complicate lower limb surgery. Abdominal and pelvic injuries have priority and should be managed before limb surgery is done. Especially in mine casualties, make sure there is no pelvic or abdominal bleeding:
- Examine the perineum – shrapnel inlet wounds?
- Check the femoral pulse beat – iliac artery injury?
- Insert bladder catheter – hematuria?
- Do rectal examination – intestinal bleeding?
- Consider peritoneal lavage

If surgery is delayed
- Soap washing: Remove clothes, scrub the limb with soap solution. Also instill soap solution into deep wounds.
- Do not delay the fasciotomy: Decompress the main compartments of the thigh and the lower leg immediately in major injuries. Apply bulky compressive dressings and elevate the legs until the surgery is done.
- Reduce fractures roughly: Fractures should be reduced in the combat area. If they are not, reduce them by manual traction immediately on admission to the clinic. Early reduction will reduce bleeding, improve peripheral circulation and reduce the soft tissue damage.

In each case – make a strategy for surgery
You cannot focus on each wound and injury separately – evaluate the total leg function:
- Injuries of both legs: Which is the limb you have to save? In some cases double amputations are unavoidable, but make every effort to save reasonable function of at least one limb.
- Multiple extensive injuries to one limb: Which injury is most important? That is, identify which injury will set limits for the final function of the limb. Example 1: It makes no sense to invest time and staff in repeated, complicated surgery to save a leg that will end up useless and painful due to extensive nerve damage. Primary amputation and prosthesis fitting will at least give a painless limb with reasonable function. The nerve injury sets the limit of surgery. Example 2: Be selective in artery reconstructions on limbs with soft tissue loss. Without sound soft tissue cover, artery rupture, thrombosis or infection will probably cause reoperations and prolonged rehabilitation. Your effort to

save a limb may in fact be a threat to the patient's life. The soft tissue injury sets the limits of surgery.

On the operating table

- Wash the limb from the groin to the toes, especially between the toes. If you suspect vascular injury, wash and prepare a vein donor area on the opposite leg. **Notice:** Normally more than one incision is necessary for proper exploration. Wash the whole circumference of the thigh.
- Apply traction before surgery on fracture injuries: Traction makes exploration and fracture reduction easier. Adhesive tape, bone pins or manual traction may be used.
- If possible, apply a deflated BP-cuff proximal on the thigh: When the fascia is incised and the soft tissue pressure diminishes, heavy rebleeding may start – inflate the cuff until the bleeding source is identified.
- Avoid stretch or pressure to the joints, bony parts of the body and on nerves (beware of the peroneal nerve) as this may cause serious damage in operations lasting more than 30 minutes.

- The access for the surgeon is improved by abduction of the injured limb. Note the traction. Access to the posterior thigh by half-side position supported by sandbags and rotation of the thigh. Lower thigh injuries are best explored with some flexion in the knee.

Anesthesia

- Ketamine anesthesia is suitable for most major lower limb injuries. As ketamine does not affect muscle relaxation, reduction of femur fractures with moderate loss of bone and soft tissues may be difficult. In that case, consider Marcaine (or bupivacaine) spinal anesthesia.
- Spinal anesthesia: Do not underestimate the large hematomas that collect around a femur fracture or under a tense thigh fascia. The patient may respond to the anesthesia with severe hypotension unless the blood loss is restored by volume preload of 1-2 liters Ringer before the anesthesia.
- Superficial injuries of the thigh: Consider femoral nerve block combined with infiltration anesthesia.

Ketamine may be a hazard after long-lasting circulatory shock: p. 149.

Side effects and precautions in spinal anesthesia: p. 684.

- Injuries below the ankle: You may use ankle nerve block or intravenous regional anesthesia.

Antithrombotic therapy: p. 594.

- Antithrombotic therapy: Complications due to venous thrombosis are common in pelvic and lower limb fractures. Patients with crush injuries, mine amputations and tourniquets during the evacuation carry a high risk of thrombotic complications. Consider starting antithrombotic therapy at the time of surgery.

Prevent multiple organ failure – two-step surgery in serious cases
Extensive pelvic and lower limb injuries carry a high risk of post-operative multi-organ failure.Patients with lasting circulatory shock, crush injury and infection cases late for surgery are at risk. For these cases early basic life support is more important than early definitive surgery and repair:

Basic life-saving surgery: p. 130.
Limb emergencies: p. 160.

- Do fasciotomies, control the bleeding and re-establish the circulatory volume. Maximum operation time: one hour.
- Consider transfusion of warm fresh whole blood to improve the coagulation in cases with hemodilution.

Transfusion of fresh whole blood: p. 268.
The choice of antibiotics: p. 652.

- Start warming: Most patients have lost temperature through the extensive wounds, blood loss and multiple cold infusions.
- Broad-spectrum antibiotics may reduce the risk of septicemia.
- When the patient is in a stable circulatory state, with a body-core temperature of 38 degr.C, do the definitive surgery. Do not hesitate to delay the surgery for 24-48 hours after injury in unstable cases.

Thigh injury

Complications are common in missile thigh injuries. Notice three important features of the surgical anatomy:

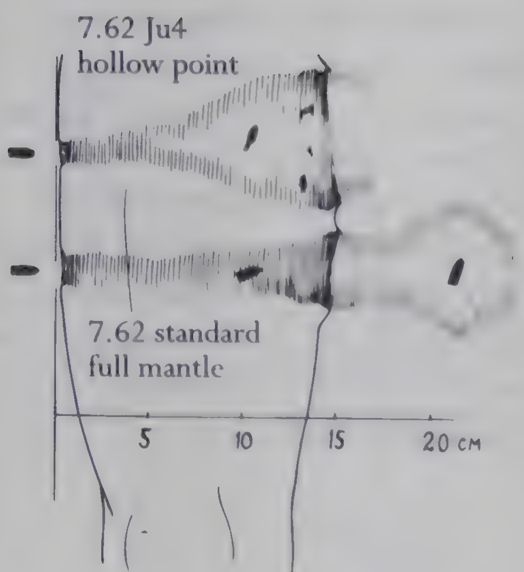
Physics of the rifle bullets: p. 78.

- **Long wound tracks – extensive necrosis:** Normally the extent of necrosis depends on the type of ammunition used. But in the long thigh wound tracks most types of rifle ammunition are retarded and cause extensive necrosis. Simply due to the large diameter of the thigh, the injury and the surgery of the thigh are more extensive than in other limb sections injured.
- **Entire muscle bellies may be necrotic:** Compared to arm injuries, the vascular supply to the long muscles bellies of the thigh is more vulnerable to missile damage. The network of collateral vessels is poor.
- **Drainage is difficult:** Blood and fluids easily collect in numerous spaces and compartments between the muscles. Unless you know the anatomy and do specific exploration of these spaces, deep pockets of infection and abscess will develop.

Surgical anatomy

All rifle bullets cause extensive soft tissue injury if the wound track is more than 20 cm long. We will compare the effect of some common battle rifles and types of ammunition: NATO AG-3 (7.62 mm), NATO M16 (5.56 mm), Russian AK-47 Kalashnikov (7.62 mm) and Russian AK-74 (5.45 mm). Seen from a practical field point of view, the speeds of the missiles from these rifles are the same. But the internal damage after a thigh hit varies – **depending on the kind of ammunition used:** Some bullets will maintain stability during the first 15-20 cm of the wound track and leave the thigh without causing major damage. Other types of bullets, even from the same rifle, will turn unstable soon after the inlet hit, and cause major soft tissue damage 10-15 cm inside the inlet wound. The figures below show the tracks of common ammunition through the soft tissues of the thigh – frontal view.

1



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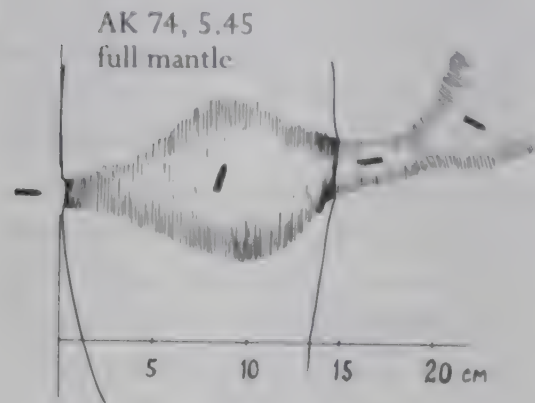

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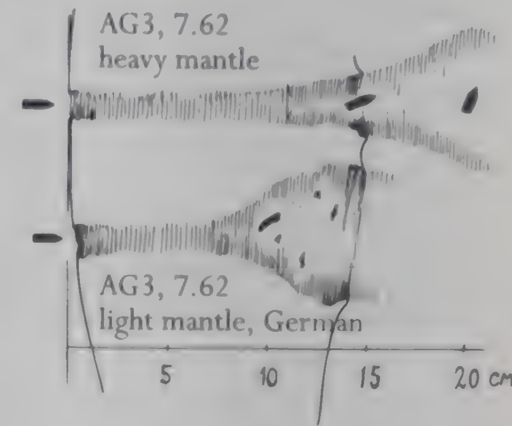
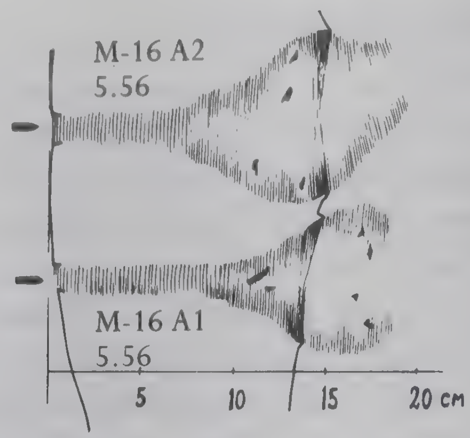


1 **The AK-47 rifle:** Compare the effect of two thigh hits from an AK-47 using different types of ammunition. The Yugoslavian type hollow-pointed, 7.62 mm bullet turns unstable 10-15 cm inside the inlet wound. The fragmentation creates a wide outlet wound: You should prepare for a wide debridement of the medial thigh, in particular, the femoral artery (the outlet side) should be explored. The other ammunition, a standard 7.62 mm full mantled bullet will gradually turn unstable 15-20 cm after the hit. Inside an abdomen it may create considerable damage. But the wound track inside the thigh is too short for maximum destabilization and damage to occur: You should not expect to find wide soft tissue damage inside that wound track, unless bone is hit.

2 **The AK-74: Early retardation – extensive injury.** The full mantled 5.45 mm bullet from an AK-74 is the most effective ammunition for limb injuries. This bullet starts its rotation just inside the inlet wound, creating a maximum shock wave damage approximately 10 cm inside the thigh. Even a tangential hit by this missile may thus create deep muscle necrosis. Note from this illustration that the internal tissue loss may be extensive – even if the outlet wound is small. **The dogma of "small outlet wounds – less internal damage" is not true.**

3 **Heavy and light mantled 7.62 mm bullets:** Compare the effect of these two hits, both from the same standard NATO 7.62 rifle. The standard bullet has a heavy copper mantle. It will not break into fragments. The bullet starts to rotate 15-20 cm after the inlet wound and continues back-to-front. Its damaging effect in a thigh hit is moderate. The German-produced light mantled 7.62 mm bullet turns unstable 10 cm after the hit. It breaks into fragments and will create maximum cavitation and soft tissue damage 10-15 cm inside the inlet. This light mantled unstable ammunition is as effective as the hollow-pointed AK-47 bullets (ill. 1).

4



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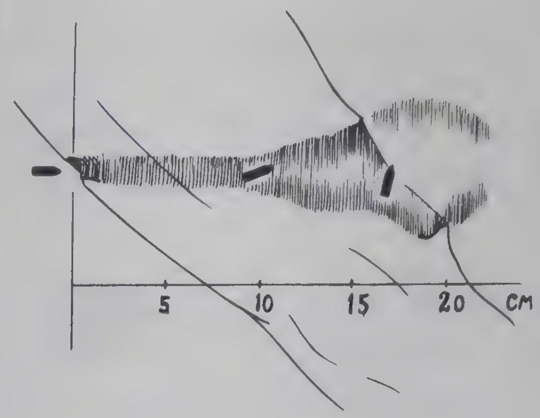
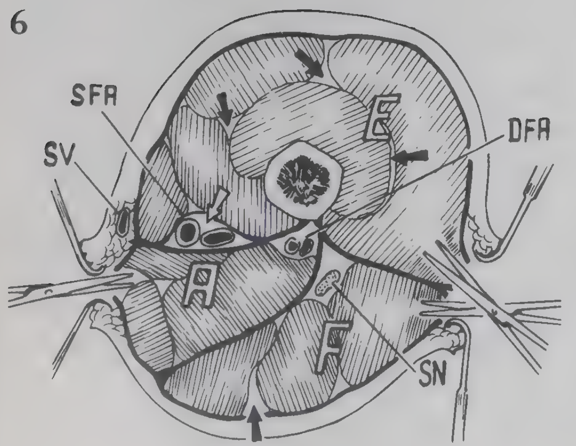


4 The US M16 rifles are operative in two models, both using 5.56 mm ammunition. The A1 is the old model ammunition. Its bullet is shorter than that of the new A2 model. The M16 is effective for limb injuries. Both types of bullets start to rotate in their track soon after the hit. Both break into fragments and create considerable cavitation before leaving the thigh. As a sign of missile fragmentation you may see a wide outlet wound with additional small outlet wounds after the fragments. Look for this informative sign before you start your surgery.

5 Oblique hit – long wound track – worse tissue damage: In oblique hits most types of bullets will turn unstable. Thus all common battle rifles may create extensive tissue damage in wound tracks more than 20 cm long. Compare this hit from an AK-47 standard ammunition with the effect of that same ammunition in ill. 1.

Few collateral vessels: Explore distal to the wound track
The arteries for the long muscles bellies of the thigh leave the femoral artery just distal to the groin. At knee level is a rich vascular network, but mid-thigh the collaterals and anastomosis are few. Consequently you may find entire muscle bellies necrotic distal to mid-thigh missile tracks.

6

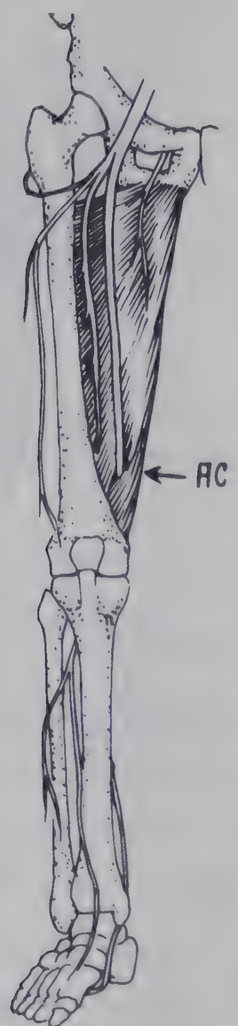


6 Cross section of the mid-thigh. Drain the deep spaces! The superficial femur fascia is strong. More than one liter of blood may collect inside the muscles under the fascia without much swelling of the thigh. Normally there is no distinct hematoma formation, but the blood collects deep in the spaces between the many muscle bellies. The only clinical sign is a tense fascia (compare to the opposite limb). Study the anatomy carefully to know the compartments and spaces where fluid collects:

- The three main compartments: The fascial septa divide the thigh into three compartments: one frontal compartment for the extensor muscles (E); one medial compartment for the adductor muscles (A); one posterior compartment for the hamstrings/flexor muscles (F). In high-energy missile injuries, fasciotomy and drainage should be done for all three compartments.
- Then explore the deep spaces: Between and along the long muscle bellies blood and fluid may collect (black arrows). Also along the main vessels and

nerves are spaces filled with loose connective tissue (white arrow). Here collection of fluid often causes minor foci of infection. If not explored and drained, even the best debridement will not prevent wound infection. (SV – the saphenous vein. DFA – the deep femoral artery. SFA – the superficial femoral artery. SN – the sciatic nerve.)

7

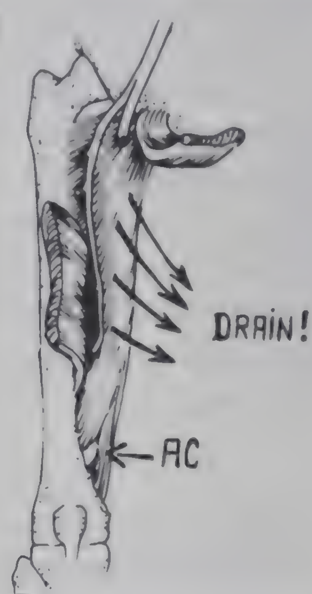


7 The superficial femoral artery carries the main vascular supply to the lower leg. It runs together with the femoral vein under the medial head of quadriceps, through the adductor canal (AC) into the popliteal fossa behind the knee. Then the artery runs superficially and artery injuries are common after missile hits. **The deep femoral artery** runs deep inside the adductor muscles close to the bone. The multiple small perforating branches of the deep artery are the main source of the large fracture hematomas of the thigh (1-2 liters).

8

8 Hematomas along the main arteries: The canal for the femoral artery (white arrow) should be explored in deep medial injuries. The canal is drained by simply splitting the roof of the canal. Access to the canal is achieved by forward retraction of the sartorius muscle as illustrated. Note the deep femoral artery running into the adductor compartment.

9

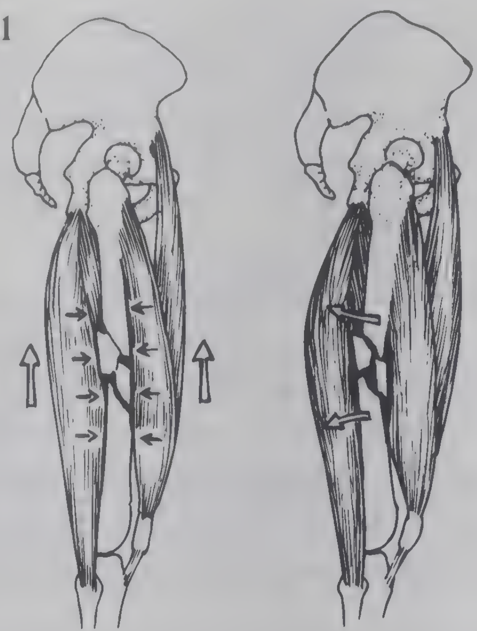


9 The deep femoral artery – a source of deep hematomas: Deep hematomas often collect along the deep femoral artery, the sources are the multiple, small but deep perforating arteries running from the deep artery. Here the main adductor muscle is shown to be cut to illustrate the space deep between the adductor muscles that should be explored and drained. The canal for the main femoral artery (also cut) through the adductor muscles into the popliteal area is shown (AC).

Biomechanics of femur fractures
Femur fractures heal well provided they are covered by viable soft tissues – and well aligned. The alignment may be difficult due to the strong pull on the femur from strong muscle groups. In each case study the muscle forces acting upon the fracture before you decide on the method of fixation. The muscle forces must be counter-balanced by the fixation you apply – be it traction, plaster cast or external fixation of the fractures.

10

11



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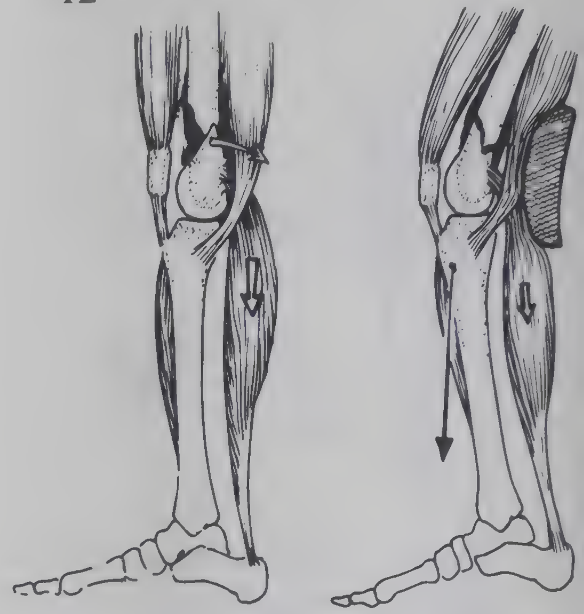
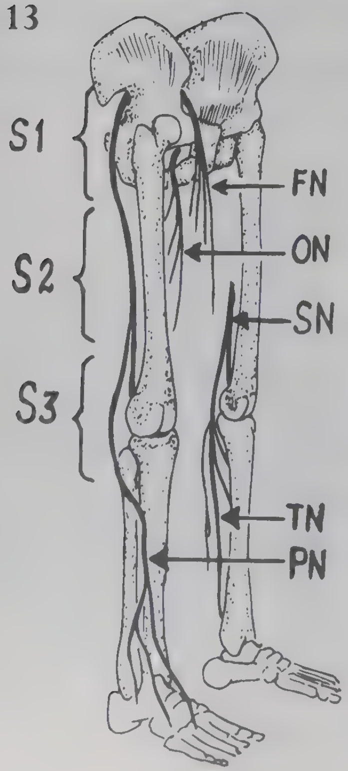


10 Displacement of trochanter fractures: Strong buttock and adductor muscles act upon the proximal fractures. Observe the pull in the medial direction upon the femoral shaft from the adductor muscles. To reduce and counter this medial pull with plaster cast management, trochanter fractures should be immobilized in abduction and flexion of the hip joint (ill. 25).

11 Displacement of shaft fractures: The quadriceps muscle in front of the femur and the hamstrings muscles posterior to the femur exert a balanced pull upon fractures of the shaft. If the fracture is not exactly reduced during primary surgery, the displacement will soon increase and result in angulation. In major mid-thigh injuries with extensive loss of either the quadriceps or the hamstring volume, a muscular imbalance will arise that may displace the fracture.

12 Displacement of distal third fractures: Note the traction from the strong gastrocnemius muscle upon the distal fracture fragment. The fragment will rotate backwards unless the pull from the strong calf muscles is counter-balanced by traction upon the tibia. Also flexion of the knee joint (pillow) will shorten the calf muscle, and reduce its force on the fracture.

13

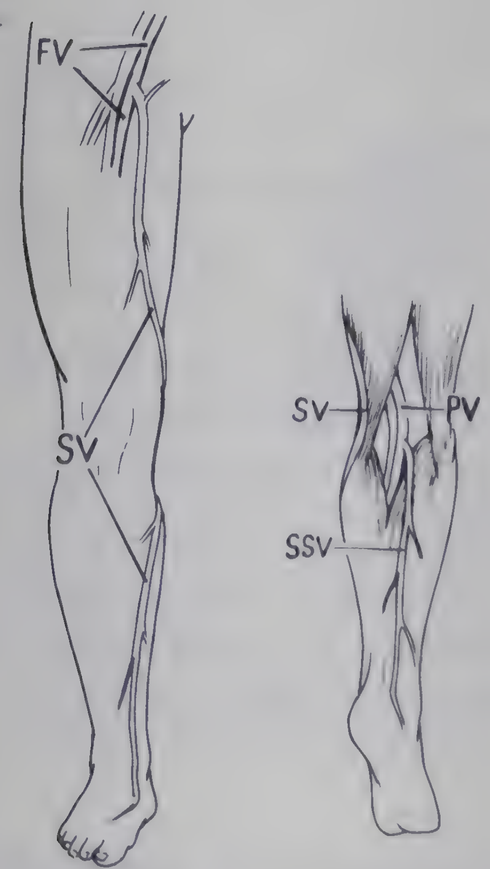


13 Three levels of nerve injuries

- The upper part (S1) of the sciatic nerve (SN) is well protected deep in the buttock muscles. Injuries to this part of the nerve are not common. The nerves to the hamstring muscles leave the sciatic nerve in the S1 area. Thus upper thigh injuries seldom affect the hamstring function.
- At mid-thigh level (S2) the sciatic nerve runs close to the bone. Here it may be damaged by fragments from compound shaft fractures. Test sciatic nerve function (p. 121).
- Most nerve injuries are seen in the distal part (S3). Entering the popliteal area the nerve becomes superficial, covered only by the popliteal fat pad. The sciatic nerve divides into the tibial nerve (TN) and the peroneal nerve (PN). **Notice:** The level of division is not constant – you may find the division inside the S2 area and even inside the pelvis.

The femoral nerve (FN) leaves the pelvis just lateral to the common femoral artery, and splits into separate minor nerves to the skin and quadriceps bellies. Injuries are not common. The obturator nerve (ON) leaves the pelvis together with the obturator artery (an important source of hematomas deep in the groin area) for the adductor muscles. Injuries to this nerve are also uncommon.

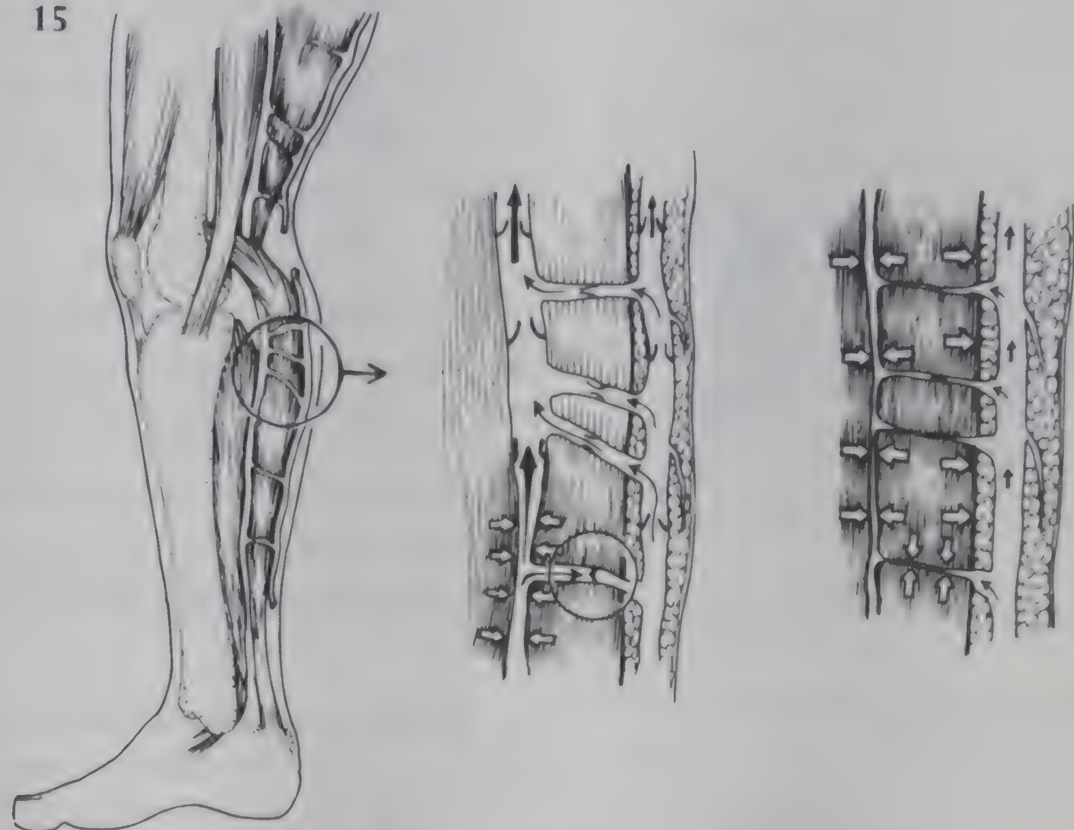
14



Reconstruct the femoral vein after
injury (FV on ill. 14).

14 Two networks of veins – one superficial, one deep: The superficial veins run superficially to the thigh fascia inside the subcutaneous tissue. The superficial veins are not essential to the general venous drainage of the limbs, unlike the deep veins. Thus superficial venous bleeding is controlled by simple ligature of bleeding points. However, avoid damaging the saphenous vein (SV) by your incisions. Grafts from this vein are used for artery reconstructions. The small saphenous vein (SSV) drains the posterior lower leg and flows into the popliteal vein (PV). The major deep veins run together with the respective main arteries. They carry the main drainage from the limb. In vascular injuries they should be reconstructed.

15



15 Compartment syndrome: Many small communicating veins connect the superficial to the deep venous network. By mechanical pressure from the muscles during walking or exercises, venous blood is pushed through the communicating veins – from the superficial into the deep network. The valves of the veins (circle) stop the blood from flowing in the opposite direction. This "muscle pump" should be actively used in anti-edema programs from the first post-operative day. If the pressure under the muscle fascia is increased (edema, hematomas) the small communicating as well as the major deep veins will collapse: The entire venous drainage is reduced → reduced blood circulation → tissues hypoxemia → increased edema → **compartment syndrome!** Active "muscle pump" exercises have no effect upon an established compartment syndrome until fasciotomy is done.

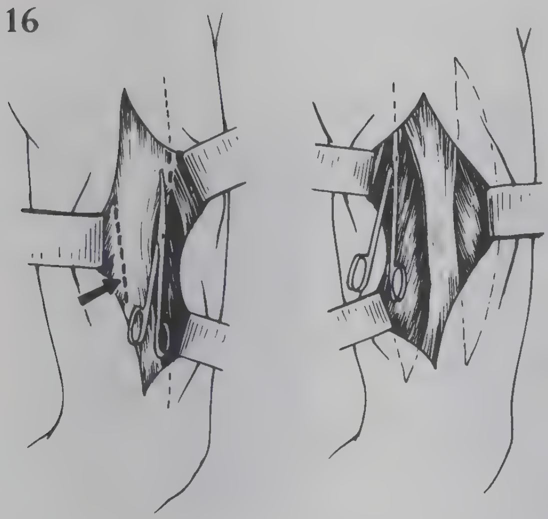
Fasciotomy and exploration

Fasciotomy is no wait-and-see procedure
Make fasciotomies when there is **risk of** compartment syndrome.
Do not wait until the syndrome is evident.

Reasons for fasciotomy: p. 177.

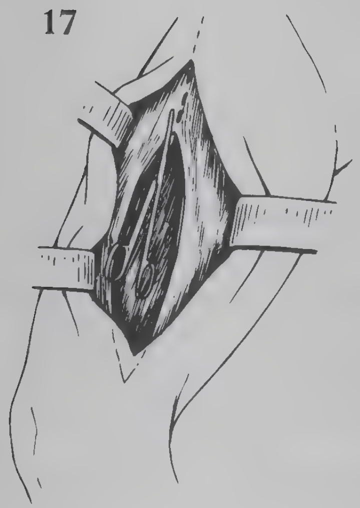
Do wide thigh fasciotomies immediately on clinic admission under low-dose i.v. ketamine anesthesia. Before lengthy evacuations battlefield fasciotomy should be done in extensive crush injuries, compound fractures and vascular injuries. Short fasciotomies do not work: The fasciotomy should reach from above the knee joint to trochanter level. Whether one, two or all three thigh compartments should be opened depends upon the injury. When emergency fasciotomy is done in the battlefield or by paramedics, the routine should be to open only the anterior compartment through a standard lateral incision. On admission to the clinic, additional fasciotomies may be done by the surgeon.

16



16 The standard lateral skin incision – fasciotomy of the anterior and the posterior compartments: The skin incision (3) in ill. 21 gives access to both the anterior and the posterior compartments. The fascia over the lateral head of the quadriceps muscle is split and the anterior compartment entered. Extend the fasciotomy under the skin upwards and downwards. The dotted line marks the incision for a posterior fasciotomy which is done by splitting the fascia just posterior to the lateral fascia septum.

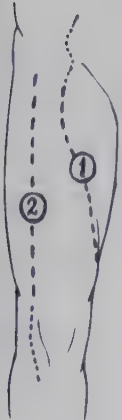
17



17 The standard medial skin incision – fasciotomy of the adductor compartment: The adductor compartment may be decompressed through an incision directly over the adductor group. But that incision does not give access to the femoral arteries. Better do the adductor fasciotomy through a standard medial skin incision (1) in ill. 18. Retract the posterior skin edge with the saphenous vein and sartorius muscle, and open the adductor compartment through a wide fascia incision in front of the saphenous vein.

The exploration
It is normally done through double skin incisions. We expect the tissue necrosis to be moderate on the bullet inlet side: Unless there are missile fractures, sufficient debridement is done by simply extending the inlet wound upwards and downwards. But on the bullet outlet side, and where there is a comminuted fracture, expect extensive tissue damage. Use one of the standard exploratory incisions for complete exploration of the wound track, including the deepest parts of it.

18



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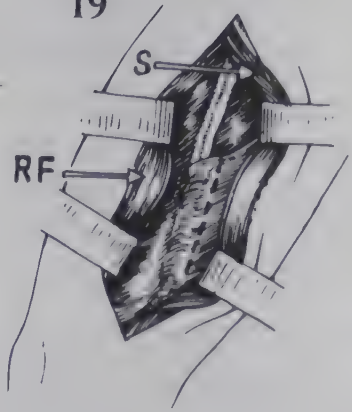
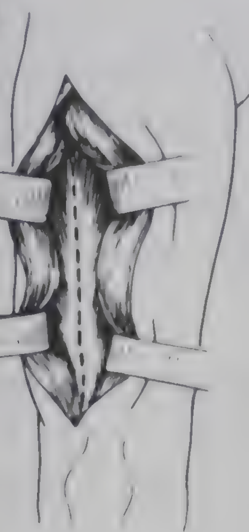


18 The standard exploratory incisions – medial (1) and frontal (2).

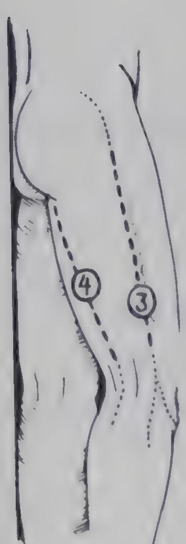
19 The medial exploratory incision is used for exploration of vascular injury, for fasciotomy of the adductor compartment and as counter-incision for debridement and drainage of fractures. The skin incision is done along the superficial femoral artery in front of the sartorius muscle. The thigh fascia is split, the sartorius muscle (S) retracted backwards, the rectus femoris head (RF) of the quadriceps muscle retracted forwards. The roof of the canal for the femoral artery may be carefully split along the dotted line.

20



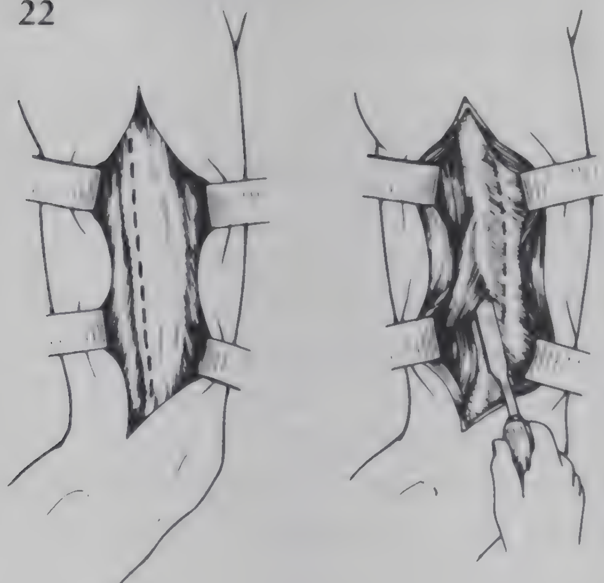
20 The frontal exploratory incision: By sharp dissection the lateral head of quadriceps is split from the rectus femoris, and retracted to expose the deep head of the quadriceps muscle. The deep head is also split sharply along the dotted line, and lifted off its femur attachment with rasps. **Notice:** The frontal incision thus does some damage to the quadriceps muscle; it impairs the knee function and control during rehabilitation. Be restrictive with the use of the frontal incision.

21



21 The standard exploratory incisions – lateral (3) and posterior (4).

22



22 The lateral exploratory incision is the standard incision for management of femoral shaft fractures. The fascia is split longitudinally. The lateral head of the quadriceps muscle is split by blunt dissection and the bone exposed. For wider exposure of the bone, the deep head of the quadriceps muscle is cut along the dotted line and lifted off the bone with a rasp or chisel. For exposure of the distal part of the shaft, the short head of biceps is released from its femoral attachment with a chisel.

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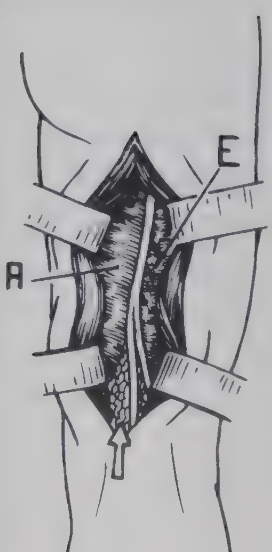


23 The posterior exploratory incision is used for exploration of the sciatic nerve and the hamstring muscles. The skin and fascia are incised in the midline and the posterior compartment entered. The hamstring muscles are separated by blunt dissection and the sciatic nerve exposed between them. The nerve rests upon the roofs of the extensor compartment (E) and the adductor compartment (A). Note the popliteal fat pad posterior to the knee joint (arrow): Resect all crushed and necrotic fat tissue to prevent infection.

Thigh vascular injury

Precautions regarding vascular reconstructions: p. 187.

- Tears of the artery: Reconstructions of the superficial femoral artery carry high risk of post-operative thrombosis even under favorable conditions. Ligature of the common femoral artery above the deep femoral artery carries high risk of secondary leg gangrene. Isolated ligature of the superficial femoral artery – if the deep femoral artery is intact – causes secondary leg gangrene in one out of three cases. In young patients the deep femoral artery may be ligated (if the superficial femoral artery is intact) without great risk of secondary gangrene.
- Intimal injury: The cavitation effect of high-energy missiles may stretch the arteries and cause rupture of the intima. The superficial femoral artery close to the adductor canal (ill. 9) and the popliteal artery are especially at risk. The early clinical signs of intimal injury are often moderate, and the diagnosis is often missed in the presence of more "dramatic" injuries. Explore the artery on suspicion. Do not wait until there is a complete tear-off of the intima: The results of early intimal repair are good, whereas late surgery is difficult.

Management of intimal injury: p. 190.

Fracture management

The femur fracture management differs according to the fracture level

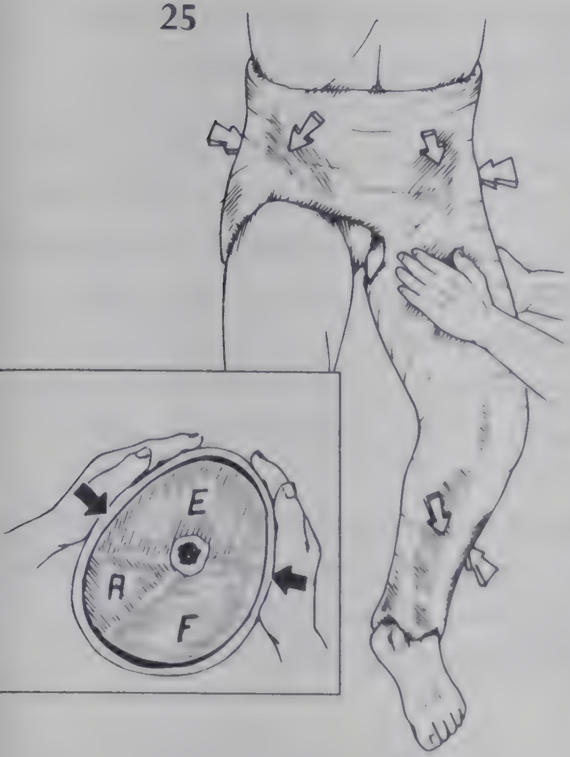
- Fractures of the trochanter area: The main problem is fragment displacement.
- Fractures of the shaft: The main problem is the soft tissue injury.
- Fractures of the distal third: The fracture may enter the knee joint with risk of arthritis. Fracture displacement may also affect the knee joint mechanism.

24

24 Fractures of the trochanter area: As the trochanter has good blood supply, the debridement of bone is conservative. Only minor bone fragments without soft tissue attachment are removed. Regarding soft tissue cover: The sartorius and tensor fascia lata muscles (ill. 8) may be mobilized as rotation flaps in cases of soft tissue loss. The fractures through and just below the trochanter heal well. The main problem is fracture displacement: The buttock muscles retract and rotate the proximal fragment outwards, while the adductor muscles displace the shaft fragment in the medial direction (ill. 10). The muscular forces are reduced by abduction and flexion of the hip joint. If traction is used for fracture immobilization, we recommend **dynamic traction:** Arrange tibial traction with the hip joint in 30-degree flexion and 30-degree abduction. Pillows should support the thigh. Start quadriceps and knee joint exercises from the first day. Check the fracture position frequently and adjust the axis of traction according to the X-ray films. When the fracture has entered the callus stage (4-6 weeks), apply plaster spica.

Tibia traction: p. 212.
Dynamic traction: p. 213.

25



25 Plaster spica management: Fractures of the trochanter area may also be managed by primary plaster spica without prior traction management. Use the plaster method of Trueta (p. 208). Apply two plaster slabs on the leg and one circular slab for the pelvis (ill. 29). Immobilize the fracture under constant manual traction, the hip joint in 30-degree flexion and 30-degree abduction. The condition for effective immobilization is careful molding of the cast (white arrows) to make it fit the contours of pelvis, thigh and lower leg. The spica should reach the rib level, but not include the ribs. The total time of immobilization is 10-12 weeks. The limb should not bear weight inside the spica until 6-8 weeks after injury. **Triangular molding of the thigh cast:** The cast must fit the triangular shape of the thigh, see the cross section. The triangular molding will prevent rotation of femur inside the cast, and make isometric quadriceps training more effective ("muscle pump" training, ill. 15).

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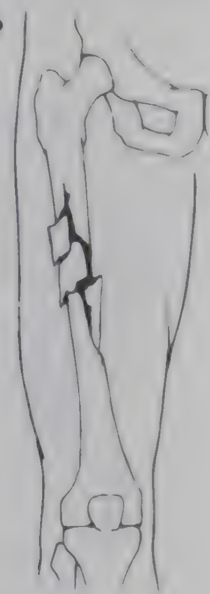

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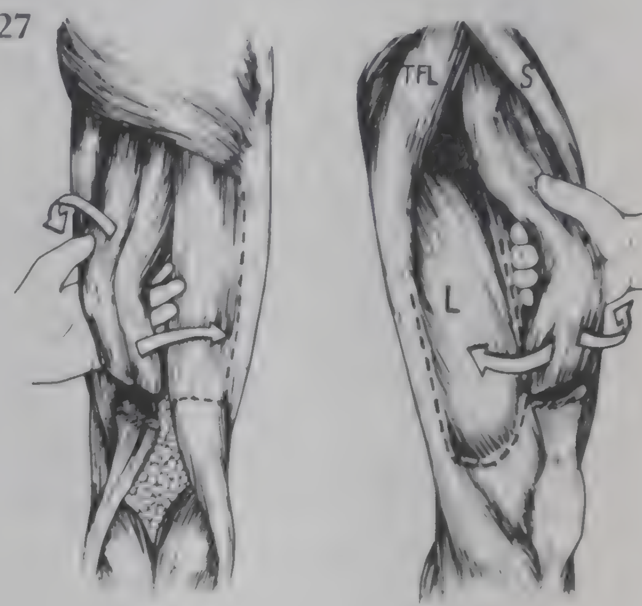


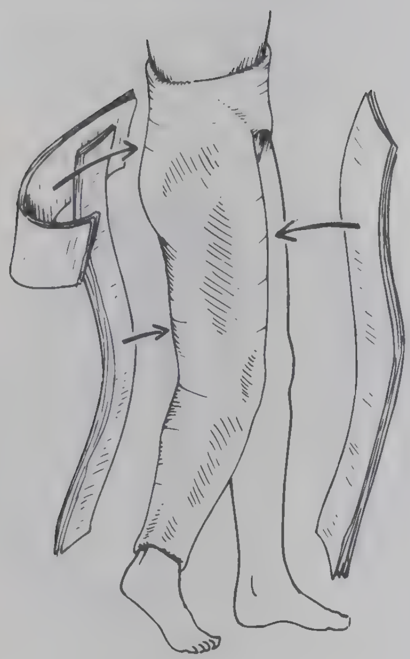
26 Fractures of the shaft: Associated vascular injury is common. In cases with damage to the deep femoral artery and extensive muscle necrosis, the bone blood supply is poor: Healing is slow and the risk of fragment necrosis and osteomyelitis is high. Do not compromise on the debridement of the soft tissues; close to the bone the debridement should be very careful. Drain the fracture field through medial and lateral fasciotomies. Where the debridement leaves the fracture with poor soft tissue cover: Mobilize local muscle flaps.

27 Muscle flaps to cover shaft fractures: One of the hamstring muscles is released close to its distal attachment, mobilized by careful blunt dissection and rotated in the medial or lateral direction to cover the defect. Or the medial head of the quadriceps muscle is released 5 cm above the patella, mobilized by blunt and sharp dissection, and rotated in either direction to cover the fracture. Also the lateral (L) head of the quadriceps muscle may also be mobilized to some extent as a flap. For minor soft tissue defects the sartorius (S) or tensor fascia lata (TFL) muscles may be mobilized.

28

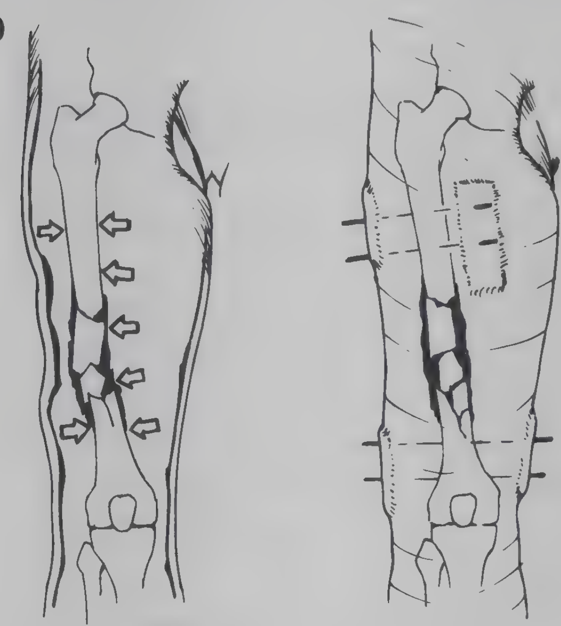
28 Dynamic tibia traction: As for fractures of the trochanter area, shaft fractures may also be managed with primary plaster cast (the method of Trueta). Another alternative is some weeks in dynamic tibia traction before the plaster cast is applied. The patient is encouraged to perform quadriceps exercises and move the knee joint at intervals (under analgesia) from the first day after surgery. Monitor and adjust the direction of the traction, the traction weights and the pillows supporting the thigh in order to achieve good alignment of the fracture within one week following injury. Note the slight curvature of femur in side-view: Support with pillows. As soon as the fracture has entered the callus stage (4-6 weeks), a hip plaster spica is applied (ill. 29).

29



29 Hip plaster spica for shaft fractures is applied under constant manual traction. Use two long plaster slabs for the leg and one circular slab for pelvis. The hip joint is immobilized in a neutral position, the knee joint flexed at 15-20 degrees. Mold the cast in a triangular fashion (ill. 25).

30



30 Plaster cast with bone pinning for unstable fractures: For good immobilization inside a plaster cast, a balanced soft tissue pressure and a well-molded cast is necessary. If the debridement ends up with extensive loss of muscles, the pressure inside the thigh is no longer balanced, and the fragments will displace. If there is also loss of bone after the debridement, the fracture is even more unstable. Double Steinmann pins proximal and distal to the fracture fixed in a well-molded plaster cast are a good method for unstable shaft fractures. The procedure in detail: p. 209.

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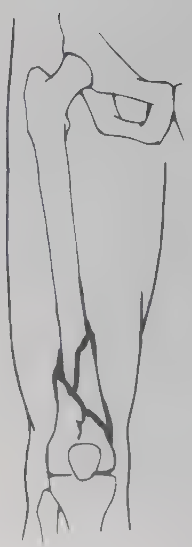
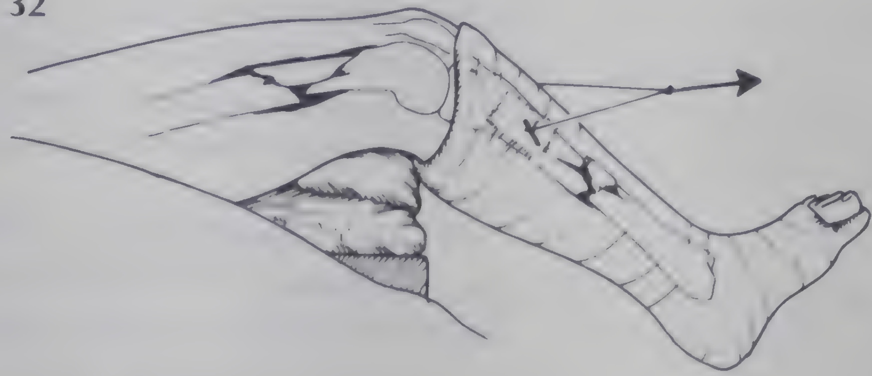


31 Fractures of the distal third: The bone blood supply is rich and the bone debridement normally narrow. The two main problems:

- Knee joint injury – does the fracture enter the knee joint? Even the best X-ray film may miss a fine fracture line entering the joint. Do sterile diagnostic puncture of the knee joint (ill. 34). Blood aspirated from the joint is diagnostic – the fracture enters the joint. Debride the soft tissues carefully, cover the fracture with viable soft tissue flaps, consider continuous joint washing (p. 220) to prevent arthritis.
- Fragment reduction and fixation are difficult: If the fracture is well above the knee joint level, primary plaster cast with 2x2 bone pins may fix it. To reduce the pull of the calf muscle on the distal fracture fragment, the knee joint is immobilized in the cast with 40-degree flexion (ill. 12). Manage displaced distal fractures in dynamic tibia traction for 4-6 weeks before a plaster cast is applied.

32



32 Multiple lower limb fractures: Combined plaster-traction management may be useful. The tibial fracture is debrided and a Steinmann pin is inserted through the tuberosity of tibia. The fracture is reduced and immobilized in a standard lower leg plaster cast (p. 206). Dynamic traction is applied on the thigh fracture from the first day after injury. After 4-6 weeks, a long foot-to-hip plaster spica should be applied and the patient mobilized.

Crush injury

ligh-energy blunt injuries and ntrapment cases: Lung contusions nd bleeding from the liver, spleen, idneys and pelvic fractures are ommon.

asic life-saving surgery: p. 130 and 60.

easons to do primary amputation: 239.

The primary management of crush injuries differs from that of missile injuries. The patient often presents a swollen limb with partial loss of nerve function and poor distal circulation. The main reason for poor nerve and vascular function is a combination of edema and hematomas under the thigh fascia, a compartment syndrome – and crush injuries of medium and large vessels and nerves. Follow a stepwise management procedure:

- **A multi-injury case – consider primary amputation:** The necrotic fields of the limb contribute to the blood acidosis and coagulation system failure often seen in multi-injury cases. If the crushed-limb patient is circulatory unstable with poor vital signs, you may risk his life trying to save the limb: Do primary amputation and concentrate on basic life support.
- **Only the limb is injured – assess the risk of limb loss:** Collect exact information also regarding how long the limb was trapped, how many hours the patient was hypotensive and the age of the patient. All these factors affect the risk of septicemia and secondary gangrene.
- **Fasciotomy and observation:** If the patient is circulatory stable and you try to salvage the limb, immediately do wide fasciotomies of the three compartments of the thigh. If the evacuation will take hours, make the fasciotomies at the site of injury before the evacuation starts. Monitor the distal circulation on the operating table for 10-20 minutes. If the muscle bellies bulge through the fasciotomies and his distal limb circulation gradually improves, and if the patient had a compartment problem, delay the definitive surgery with debridement and fracture management for 24 hours until the local circulation has improved.
- **Artery exploration and reconstruction:** If the distal circulation does not improve within 10-20 minutes after the fasciotomy, there is probably one or more tears or intimal injuries in one of the femoral arteries. Explore the actual artery. If the damage is localized, consider reconstruction if there is no extensive loss of soft tissues.
- **Artery exploration – no vascular surgery:** If the vascular damage is extensive and includes several segments of the vessel – and affects minor as

well as major arteries – this is not a case for vascular surgery. Concentrate on exact debridement of the tissues along the main arteries. Elevate the limb, start anti-edema exercises under analgesia and monitor the circulation closely: There is a risk of distal gangrene as well as thrombosis of the femoral and iliac veins.
- **The nerve function – observation:** Concentrate on exact debridement of soft tissues around the main nerve trunks, but leave the nerves alone. The nerve function will probably improve slowly. The final result cannot be assessed until six months after injury.
- **Antithrombotic therapy:** Crush cases carry high risk of thrombotic complications. Give dextran or heparin infusions before and during surgery.
- **Antibiotics:** In serious cases trapped for hours there are probably patchy necrosis along the entire limb. As you cannot expect to identify and debride all minor necrotic areas, the risk of wound infection and septicemia is high. Consider broad-spectrum antibiotics before and during surgery.

The choice of antibiotics: p. 649-655.

Thigh amputations

Delayed primary closure
Primary closure normally causes infection; so manage the wartime amputations as you would any other wartime wound: Either leave the amputation stump wide open for 4-5 days, or do the myoplasty over tube drains at the time of primary surgery, but delay the fascia-skin suture for 4-5 days.

Amputation surgery: p. 237.

High thigh amputation
- Save maximum bone length: To control a weight-bearing prosthesis, the bone stump must reach 10 cm below the trochanter. Flap amputations save more length than the guillotine method. You may use anterior-posterior soft tissue flaps or medial-lateral flaps.
- Decompress the stump: The flap incisions are extended as double fasciotomies both for decompression of the stump, and for exploration proximal to the amputation level.
- Drain the stump and the fasciotomies well (the Trueta method).
- Stable centering of the bone inside the soft tissues is important, especially in the short stump. Trim the muscle bellies to avoid a clumsy stump, and do myoplastic closure: Suture the adductors to the lateral part of quadriceps, the hamstrings to the quadriceps over a tube drain. Close the fasciotomies. Trim and close the fascia-skin flaps over the myoplasty with deep interrupted mattress sutures.
- Avoid hip joint flexion contracture: Apply a Trueta hip plaster spica at the operating table after primary surgery and after stump closure.
- Fix a temporary training prosthesis to the plaster cast.

The IPOPF method for prosthesis training: p. 242.

Mid-shaft amputation
- A difference of 5 cm bone length has no practical importance. Guillotine amputations may thus be used, even if the bone must be trimmed for some cm at the time of stump closure.

nee joint disarticulation, the procedure: p. 241.

ɔint injury – the principles of management: p. 217.

- The flap method: Design the flaps of different length to prevent the suture line being located on the weight-bearing surface of the stump.
- The stump is closed with myoplasty and delayed primary suture.
- Consider post-operative plaster cast with a training prosthesis.

Distal femur amputation

Hinged knee prosthesis: The ideal bone amputation level is 12-15 cm above the knee joint. For a plain non-hinged prosthesis, save maximum stump length.

Knee joint disarticulation

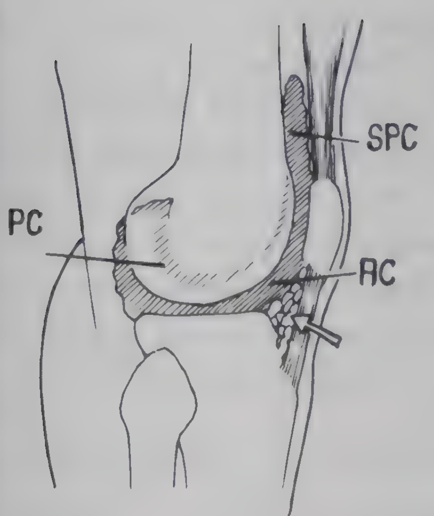
The disarticulation is a non-traumatic, rapid and simple method.
The indications:
- To free trapped patients
- Life-saving surgery in unstable multi-injury patients
- Amputations in old patients in poor general condition

Injury to the distal thigh and the knee

Surgical anatomy

Three features of the knee joint anatomy make surgery difficult
- The joint is composed of several compartments. Study the joint anatomy carefully, especially the extension of the superior and posterior compartments to be able to explore the joint properly. Missed dirt, shrapnel and perforations may cause arthritis and a lost joint.
- The soft tissue protection to the anterior part of the joint is poor. In cases with extensive soft tissue injury it is difficult to close the joint.
- The joint mechanism is complex: There is a mixed sliding-rotating-hinge motion. Minor ligamentous injuries may cause a major stability problem. Know how to test the joint mechanism in order to make up a correct plan for surgery in each individual case.

3



33 The compartments of the knee joint: There are three main compartments. Wash all compartments with normal saline; use a large syringe with a 15 cm soft plastic tube.
- The superior compartment (SPC) under the patella may extend as far as 12 cm from the tibio-femoral joint level under the quadriceps muscle (ill. 34). Fractures of the distal femur and wound tracks through the distal thigh may enter the joint through the superior compartment – there is an open joint injury.
- The anterior compartment (AC) is located behind the patellar tendon. Note the pad of fat tissue (arrow) forming the frontal wall of this compartment. Also posterior to the joint around the popliteal vessels there is a pad of fat. Necrosis and hematomas of the fat pads may be a source of joint infection: Debride the fat tissue meticulously.

- The posterior compartment (PC) is located between the two femur condyles. Loose bodies (necrotic cartilage or bone fragments) often hide in the posterior compartment: Wash it carefully; consider exploratory incisions at "the posterior corner" (ill. 44) for exploration.

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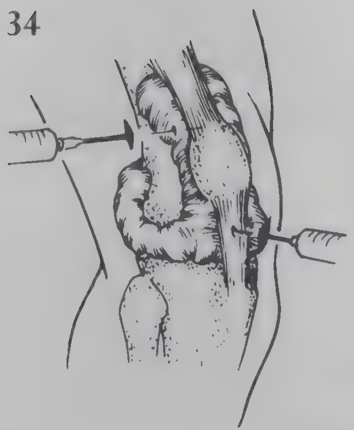

34 Diagnostic puncture: If you suspect joint injury or infection, do not hesitate to perform a diagnostic puncture. Work sterile, under local anesthesia, with a large-bore needle. These are the standard sites for joint puncture: 1 cm above the upper lateral corner of patella, or through the patellar tendon and the pad of fat into the anterior compartment. Normal synovial fluid is shiny and colored like urine. Thick dull fluid indicates infection. Bloody synovial fluid indicates penetrating joint injury: Explore, identify, debride and close the wound track.

35


35 The soft tissue problem: The knee joint is well vascularized by a network of collateral arteries. Generally the debridement of skin and subcutaneous tissues is limited. Beware of wounds of the lower anterior aspect of the joint (shaded): In this area the skin blood supply is poor, no muscles protect the joint, healing may be delayed – unless soft tissue flaps are mobilized for joint closure.

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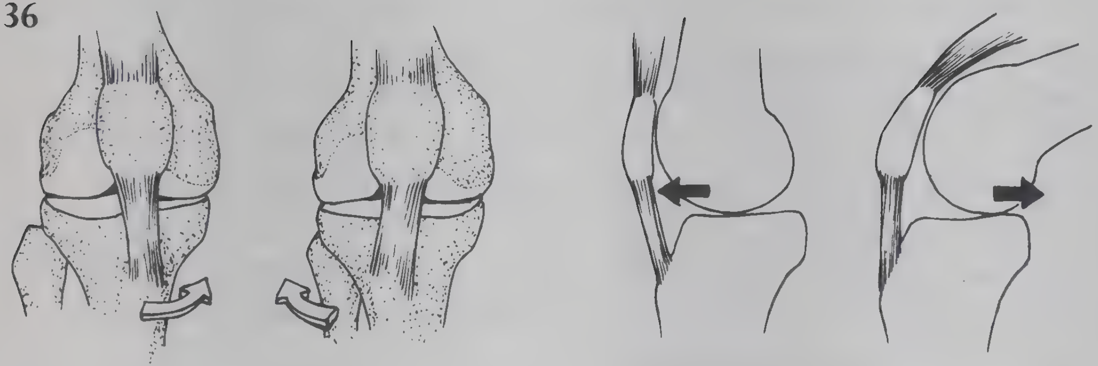

36 The complex knee joint mechanism: Principally the knee is a hinge joint, but there is also some rotation and a slight sliding of femur on tibia during flexion-extension. The wide range of motion makes the joint stability a problem.

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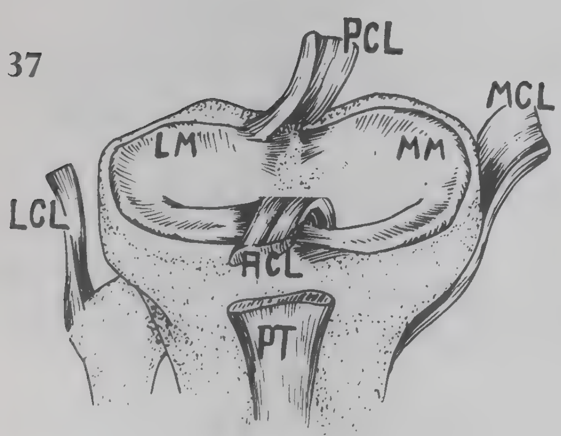

37 Knee joint stability: To stabilize the complex motion, the supportive mechanism must be complex as well. Here the joint is shown to be disarticulated and the femur removed for reasons of illustration:

- The quadriceps muscle is the single most important stabilizer. It works on the patellar tendon (PT), but is also connected directly to the capsule through its medial and lateral tendinous expansions (ill. 49). Defects of the main ligaments may be partly compensated by strong quadriceps action. Handle the quadriceps muscle with care during surgery: Choose your incisions so you do not interfere with the quadriceps' joint function. Also quadriceps training is important after knee injury: Isometric exercises should start the first day after injury (p. 632).
- The medial and lateral collateral ligaments (MCL and LCL) are external ligaments that stabilize the joint against stress from the sides (ill. 39). The ligaments are interwoven in the tendon-capsule apparatus.

- The anterior and posterior cruciate ligaments (ACL and PCL) are interior ligaments stabilizing the sliding motion.
- The medial and lateral meniscus (MM and LM) are semi-lunar cartilaginous structures exactly fitting the contour of the femur condyles. Injury to the semi-lunar cartilage may lock the hinge movement of the joint.

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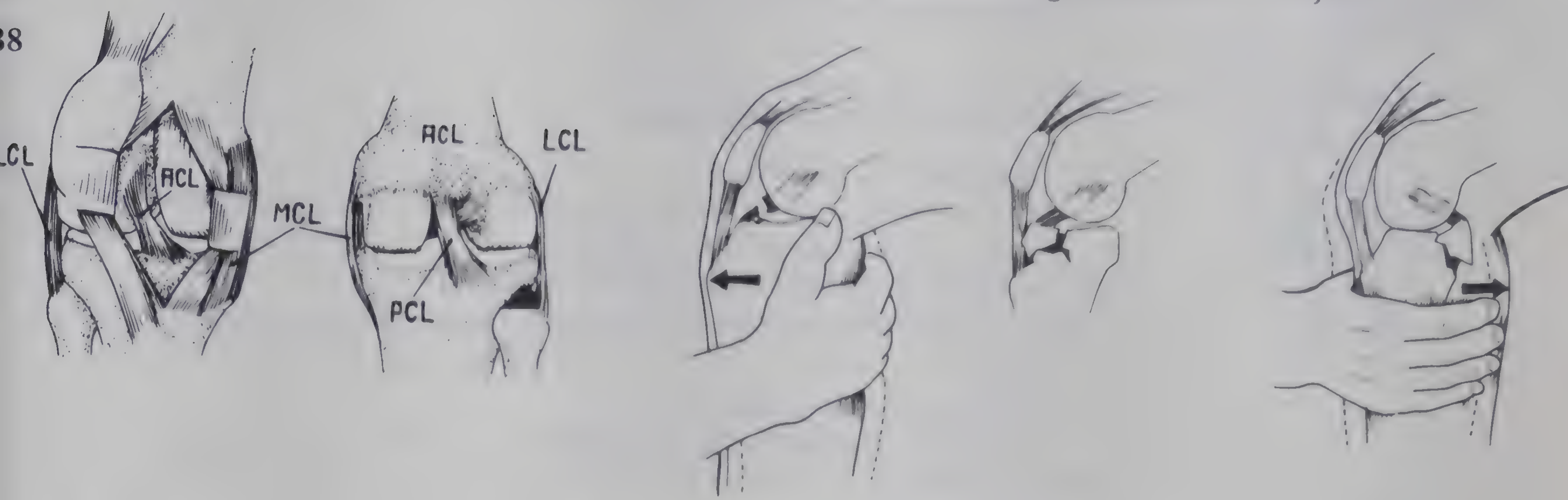

38 Testing the cruciate ligaments: A torn cruciate ligament or a fracture through its bony attachment will produce a draw instability of the joint, a forward or backward draw depending upon which of the cruciate ligaments are torn. Test all joint injuries for draw instability.

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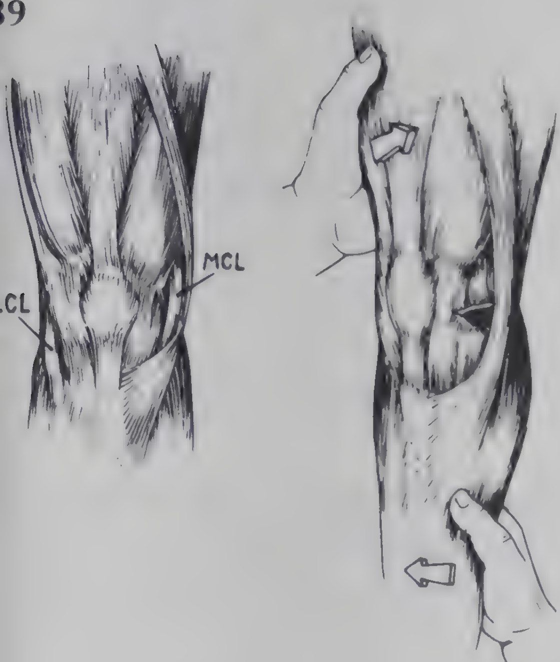
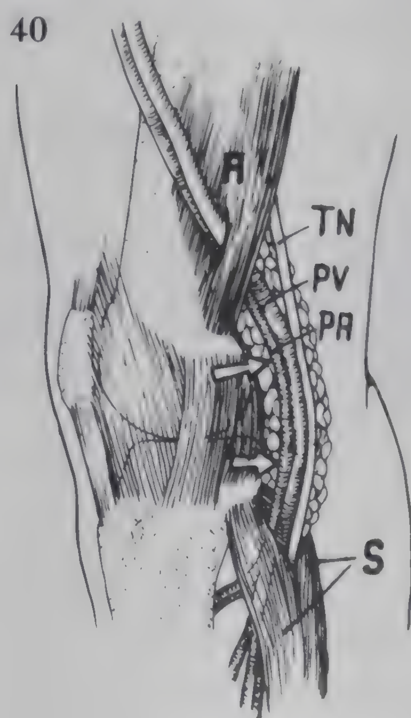
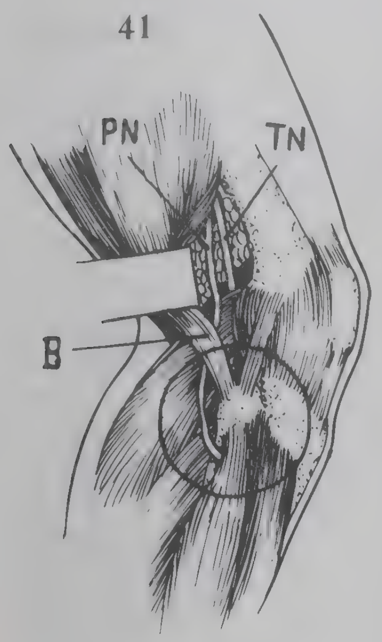


39 Testing the collateral ligaments: Injuries to the collateral ligaments cause side instability. In this case the injuries to the medial capsule and the collateral ligament are diagnosed by side-stability testing.

40



40 Associated popliteal artery injury: Intimal detachment or tears of the popliteal artery (PA) or vein (PV) are common in penetrating and blunt high-energy injuries. There is a close relationship between the femur condyles, the posterior joint capsule and the popliteal artery. Fracture fragments may tear the vessels. More common are intimal injuries: The artery is "fixed" proximal and distal to the popliteal area – in the adductor channel (A) and crossing through the sartorius muscle (S) together with the tibial nerve (TN). Between these points, the artery may be stretched in posterior dislocations of the femur condyles, causing rupture of the artery's intima and partial occlusion of the artery.



41 **Watch the peroneal nerve!** The nerve (PN) runs under the biceps muscle (B), subcutaneously around the neck of the fibula into the lateral muscle compartment of the leg. Close to the fibula (circle) the nerve may be damaged by careless surgery, by pressure damage on the operating table or pressure from a poor plaster cast. The signs of peroneal nerve injury: p. 121. TN: the tibial nerve.

Preparations for surgery

If surgery is delayed

- Do not delay the fasciotomy in major injuries: Decompress the compartments of both lower leg and thigh.
- Instill dilute soap solution into deep wounds.
- Consider intra-articular injection of penicillin (5-10 mega IU).

On the operating table

- Apply a deflated BP-cuff mid-thigh: You may need a bloodless field for joint exploration.
- Wash the whole circumference of the leg from mid-thigh to the ankle. Also wash a vein donor area on another limb if you suspect popliteal vascular damage.
- Protect the peroneal nerve and bony prominences: Pad the limb on the table.
- The position: Both posterior and anterior exploration is best done with 30-45-degree flexion of the joint. To enter the joint: Hang the leg over the end of the table, the knee joint in 90-degree flexion.

Anesthesia

Both spinal bupivacaine and i.v. ketamine anesthesia is used for knee surgery. Isolated explorations of the joint may also be done under local anesthesia: Instill 40 ml dilute local anesthetic in the joint, supplement with infiltration of the skin and capsule.

Exploration for missile injury

Reasons to do primary amputation: p. 239.

The management strategy

- Examine the vascular and nerve function: If both the tibial nerve and the popliteal artery are torn, primary amputation is indicated.
- Reconstruction of the popliteal artery has priority before the joint injury.
- The blood supply to the soft tissues of the knee joint is rich. The debridement should generally be moderate.
- Synovium and the synovial fluid are the main protection against joint infection, a dry and open joint will become infected: Leave enough healthy synovium and/or skin to close the joint after the debridement.
- Wash all joint compartments thoroughly with normal saline. Also wash with soap solution if the joint is very dirty.
- Be careful to excise all crushed and non-bleeding fat tissue – inside and outside the joint.

The management of joint injuries: p. 217.

- Smooth tears and fractures of the joint cartilage with a knife.
- Excise tags of the cartilage and meniscus.
- Leave tears of the main ligaments for secondary reconstruction.
- If the joint injury is less than eight hours old, close synovium with continuous sutures. Instill penicillin (10 mega IU) in the joint. Close the capsule and skin.
- If the joint injury is old and infected, arrange continuous antibiotic washing of the joint.

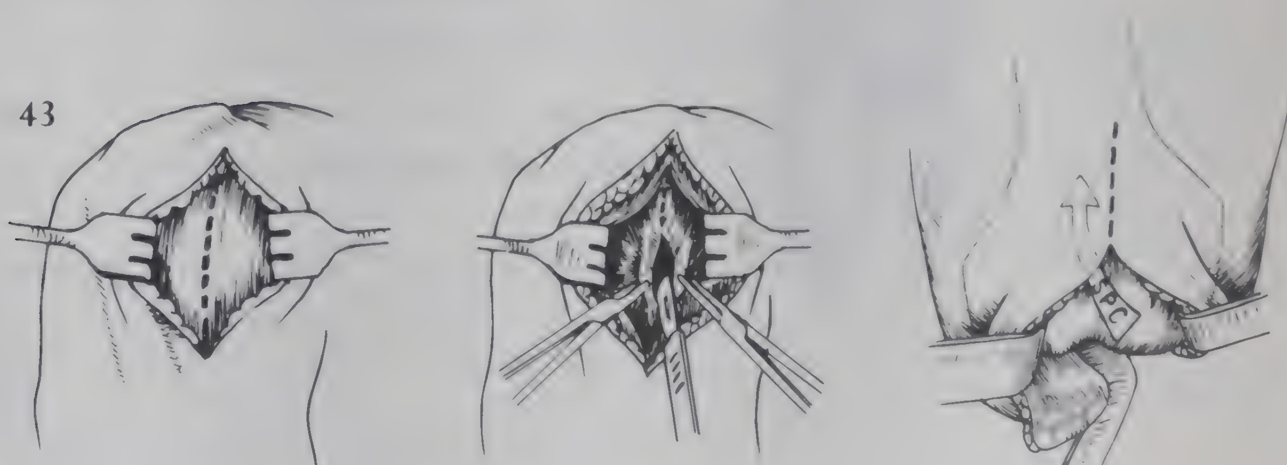
Popliteal injury

As a routine, explore the popliteal structures in high-energy injuries – especially in cases with displaced fractures of the distal femur or the tibia end, and if the distal circulation is impaired. The intimal artery's injuries have few early clinical signs: At the knee joint the collateral small knee arteries can support the distal circulation to some extent – but with progressive tear-off of the intima the lower leg becomes cool and gradually paralytic. Ligature of the popliteal artery causes secondary gangrene in one out of two cases: Reconstruct the artery.

42

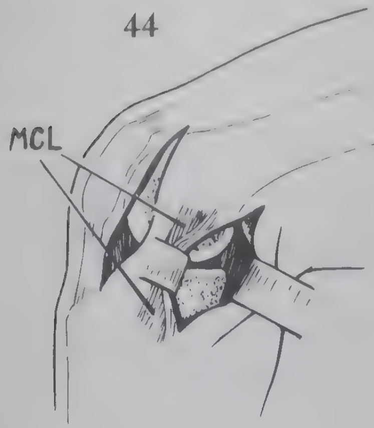
42 Exploration of the popliteal structures: Use S-shaped skin incision to avoid excessive scarring. Follow the superficial veins by careful dissection into the popliteal fat pad: The veins will guide you to the popliteal vein (arrow). By careful dissection explore the popliteal artery and the tibial nerve under the vein. Beware that the retractors may damage the tibial (TN) and peroneal nerve (PN). Isolate the artery between clamps and do a short arteriotomy if you suspect arterial damage. For further exploration of the vessels, the incision is extended in the proximal direction through the medial hamstring muscles, or into the lower leg by splitting the calf muscle.

43



43 The medial exploratory incision: Incise the skin, subcutaneous fat and capsule 1-2 cm medial to the patella. The synovium is lifted between clamps, split and retracted (blunt retractors). Identify the medial meniscus, the anterior cruciate ligament and the medial femur condyle. Wash all compartments of the joint. You may extend the incision proximally into the quadriceps tendon expansion, retract the patella and explore the superior compartment (SPC).

44



44 **Double exploratory incisions:** To explore the posterior joint compartment, the capsule is split longitudinally at the posterior medial (and/or lateral) "corner" – behind the collateral ligament.

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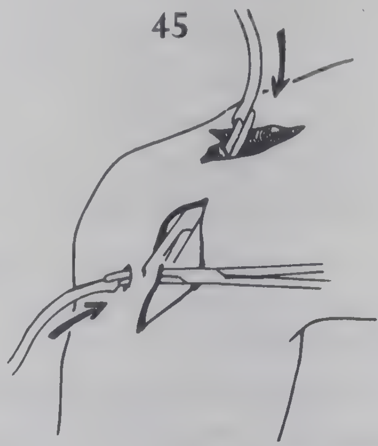
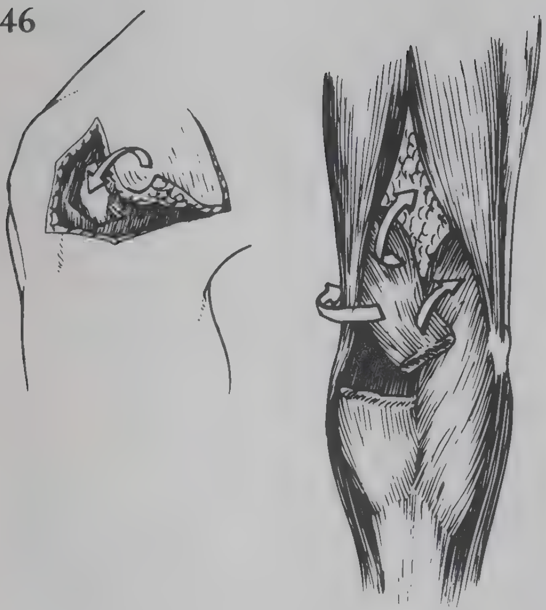


45 **Continuous washing of the joint:** Cut some side holes in the tube of an infusion set and railroad it into the superior joint compartment. For drainage, a thin bladder catheter is railroaded into the joint through a separate stab incision and connected to a urine bag. The joint is closed and a saline-penicillin infusion run for 1-3 days.

Extensive joint injury

> Closing the joint has first priority – ignore the joint stability: Mobilize soft tissue flaps, even resect bone or fracture fragments if that is necessary to close the joint.

46



46 **Soft tissue flaps to close defects of the capsule:** Improvise in each case – use flaps of synovium, skin flaps or muscle-skin flaps to fill in defects after the debridement. A broad-based full thickness skin flap may be raised along the muscle fascia, and rotated onto anterior defects. The gastrocnemius muscle flap covers defects of the posterior capsule: Use either the medial or the lateral head of the muscle. If no local flaps are available, consider cross leg flap (p. 257). If you find it impossible to close the joint, the case is probably one for arthrodesis or amputation.

Open joint fractures

> - **First priority – prevent joint infection:** Remove all necrotic soft tissue and bone fragments with poor soft tissue attachment. Ignore the joint stability: At this stage the main threat to the future joint function is infection. Cover the fracture with viable soft tissue flaps.
> - **Second priority – manage the fracture:** The definitive reduction and fracture fixation may be delayed for 1-3 weeks until the soft tissues heal without infection.

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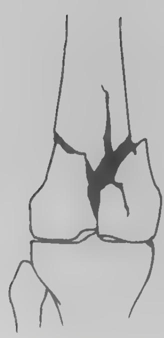
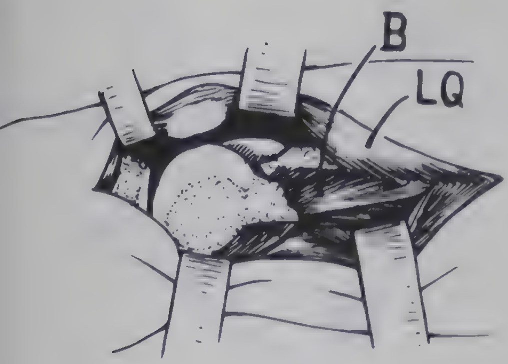
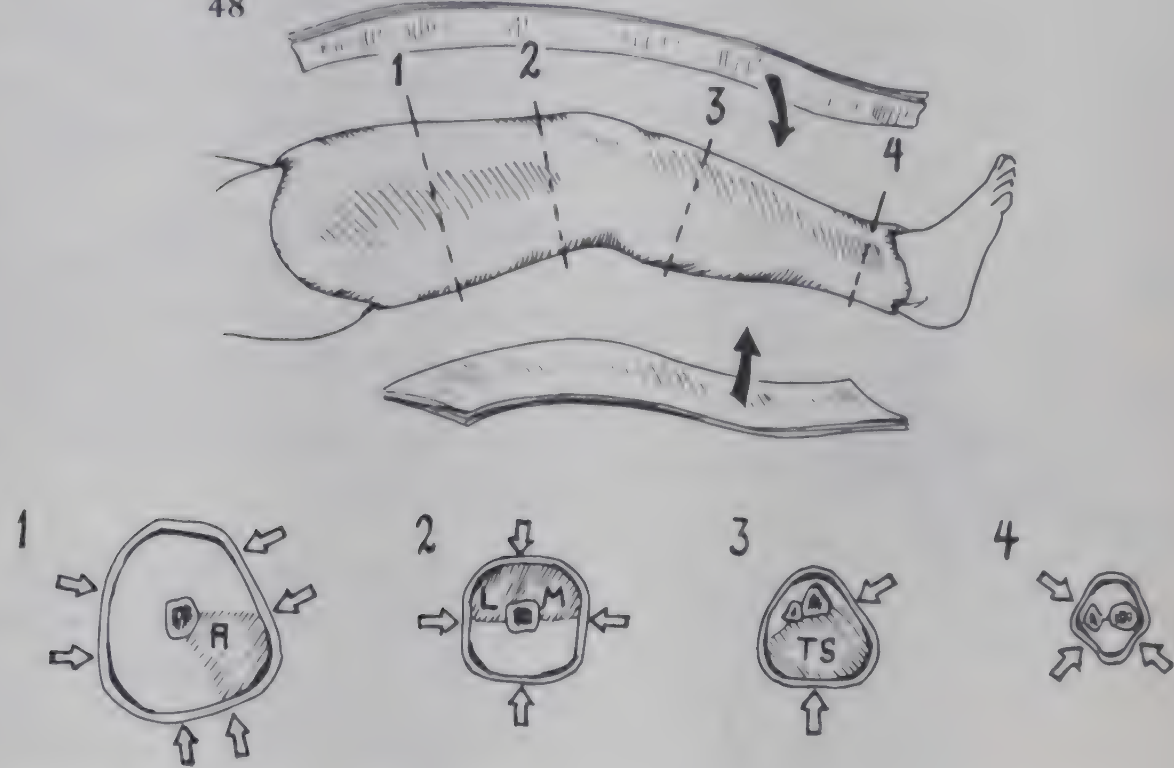


47 **Exploration and dynamic traction on distal femur fractures:** The bone and soft tissue blood supply to the distal thigh is rich and the debridement is generally moderate. On the X-ray films the fracture position may seem reasonable, but you should still explore the fracture closely: Fragments of bone



may have torn the joint capsule, and muscle may interpose in the fracture line making reduction impossible. Expose the fracture through a long lateral incision: Retract the lateral head of quadriceps and the biceps muscle. Often, as in this case, the short biceps muscle is interposed in the fracture – release it. The gastrocnemius muscle will displace the distal fragment (ill. 12). To prevent angulation, both traction and plaster cast fixation must be done on a flexed knee. Arrange dynamic tibial traction on comminuted fractures: Start careful flexion-extension motions of the knee joint (mean flexion 30 degrees) from the first day. The range of motion should be restricted during the first four weeks. Consider plaster cast application within 4-6 weeks.

48



48 Plaster cast management: Pad the bony prominences. Apply anterior and posterior slabs under constant manual traction on the foot, the knee joint flexed at 15-20 degrees, the ankle in a neutral position. Circular turns of plaster fix the slabs and finish the cast. The cast should be worn for 8-12 weeks depending upon the fracture. After 6-8 weeks careful weight-bearing is allowed. Let the fracture pain adjust the weight load. **Note** some points regarding the plastercraft:

- The cast should reach from ankle joint level to the femur trochanter.
- Slab application is easier if you apply **one** layer of circular plaster (rolls of 15 cm) inside the slabs to which the slabs will stick.
- Mold the cast triangular at the thigh level to fit the adductor muscles (A).
- Mold it quadratic above the joint to fit the medial and lateral quadriceps (M, L) and the hamstring tendons.
- Mold it triangular below the joint to fit the triceps surae muscle (TS).
- Mold it quadratic above the ankle to fit the malleolar contour.
- In tibial condylar fractures, the cast should also include the ankle joint.

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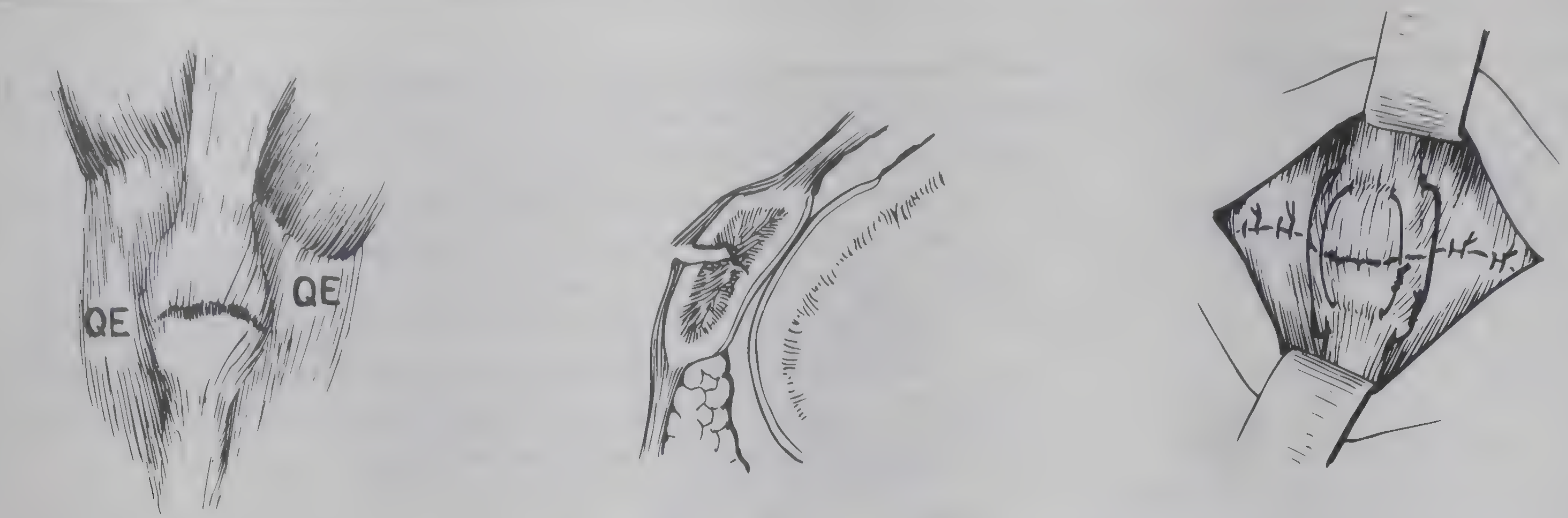

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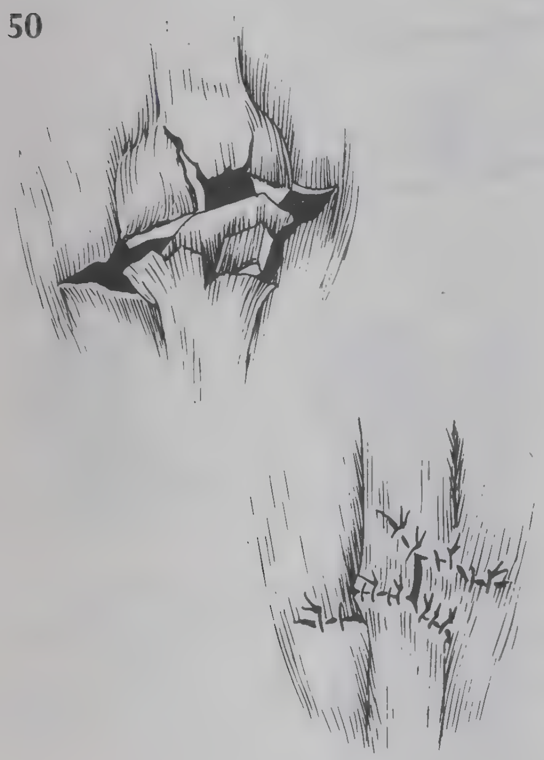


49 Fractures of the patella: If the patient is able to raise a straight leg, the patellar fracture is stable, and the treatment is simply debridement and a standard knee plaster cast with the knee in full extension for six weeks.

- Is the fracture complete or not? If the inner table of the patellar bone is not fractured, the fracture will not displace.
- Is the quadriceps tendon expansion (QE) torn or not? If undamaged, the expansion will fix the fracture, and you do not need to wire the patella.

If the fracture is complete and the quadriceps expansion torn, the fracture is reduced and fixed with strong absorbable sutures or soft steel wire. The wires are applied through the tendon and capsule as close to the bone as possible. One of the wires should be located deep, the other more superficial to compress both the inner and outer patellar table. A standard knee plaster cast is worn for 6-8 weeks.

50 Comminuted fractures – excision of the patella: The excision is done close to the bone, inside the quadriceps expansion. When the bone is completely removed, the expansion and the patellar tendon is approximated and sutured with strong silk sutures with full extension of the joint. Steinmann pins through the tendon proximal and distal to the patella may be used to relieve the tension on the tendon suture. The pins are fixed in the plaster cast which is worn for six weeks.

Fractures of the end of the tibia

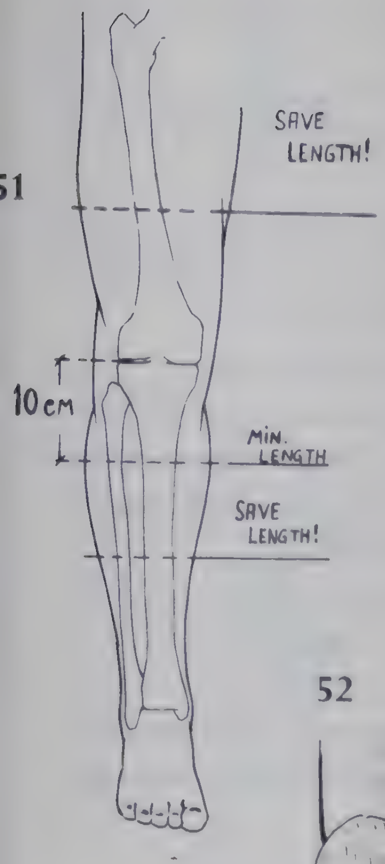
On the one hand – the proximal plateau of tibia carries a heavy weight load, and the fractures should be carefully reduced to maintain the joint mechanism. Normally the fragment displacement is worse than you can imagine from the X-ray films. On the other hand – there is high rate of osteomyelitis and knee joint arthritis after open fractures to the tibia end. The reasons for the poor results are extensive reconstructive surgery and bone grafting being done at the time of injury – when the fracture field has poor blood perfusion and necrotic soft tissues are present. Instead, we recommend a two-step procedure for comminuted plateau fractures.

- **First operation – clean the field, concentrate on soft tissue cover:** Debride the soft tissues carefully. Reduce the fracture fragments roughly, and mobilize muscle or full thickness skin flaps to cover the fracture field with well-circulated tissue. Arrange for continuous joint washing with antibiotic solution. Arrange for dynamic traction (calcaneus or lower tibia pin): Encourage continuous but careful flexion-extension exercises for 5-15 days. Dynamic traction will assist in reducing the fracture fragments.

See also p. 222.

The Trueta method: p. 182 and 208.

51



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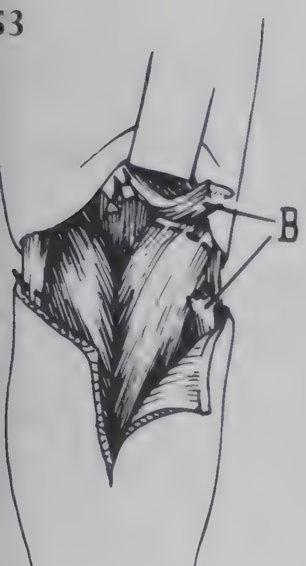

• **Second operation – reduce the fracture, reconstruct the joint:** When the soft tissues are healing and the joint closed without infection, re-explore the fracture. Reduce the fragments so that no steps in the joint surface exceed 5 mm. Insert bone chips from the pelvic wings in the fracture line to stabilize the fragments. Insert gauze drains and apply a Trueta plaster cast, the knee joint flexed at 20-30 degrees.

Amputations at the knee joint

51 Amputation levels

- Above the knee joint: If prosthesis with hinged knee mechanism is available, the level of amputation is 10-12 cm above the knee joint.
- If only non-hinged prosthesis is available, try to save length: Amputate through the distal femur or through the knee joint.
- Below the knee joint: The tibia stump must be at minimum 10 cm long in order to control a lower leg prosthesis.

52 **End-bearing distal femur amputation:** A long anterior and short posterior soft tissue flap is standard. If the muscle flaps are thick, the design of the flaps is of less importance. Isolate the patellar tendon and patella by sharp dissection, and cut the quadriceps tendon just above the patella. Cut the hamstring tendons close to their attachment to reduce bleeding. Ligate the popliteal artery, and cut off the popliteal nerves as proximal as possible. Cut the femur through or just above condylar level, trim the the bone edges. Leave the stump open for 5-10 days; close when the tissues are clean. Myoplasty will give better muscular control of the stump: Suture the lateral head of quadriceps (LQ) to the medial hamstring muscles. Suture the medial head (MQ) to the lateral hamstring muscle. The skin flaps are trimmed to locate the suture line behind the weight-bearing surface.

53 **Knee joint disarticulation** is less traumatic, and should be used in multi-injury cases, where the operation time must be short, on old patients, and to free trapped limbs. The procedure (also study p. 241): The skin flaps are designed with a long anterior flap, or with medial-lateral flaps. A posterior midline incision below the amputation level makes the popliteal dissection easier. Carry the incision straight through the capsule and the patellar tendon. Cut the cruciate ligaments through their tibial attachment. Identify the vessels and nerves in the popliteal area; ligate the vessels doubly, and cut the nerves at the highest possible level. Then the biceps muscle (B), the medial hamstrings, the medial and lateral gastrocnemius muscles – all close to their attachment to bone.

After 5-10 days the stump is clean and closure is done: Suture the patellar tendon to the posterior cruciate ligament and capsule, the hamstrings to the anterior joint capsule. (There is no need to fix the patella to the femur condyles). The skin-fascia flaps are trimmed to locate the skin suture line posterior to the weight-bearing surface of the stump. Skin and fascia are closed all-in-one with deep interrupted sutures.

Lower leg injury

Surgical anatomy

Of all limb injuries, wartime injuries of the lower leg carry the highest rate of complications

Note special features of the lower leg injuries that complicate healing:

- The fractures are unstable: The soft tissue support for tibial shaft fractures is poor.
- Poor tissue perfusion – delayed healing of fractures: For fracture healing, viable soft tissue covering the fracture is important. But the medial-anterior aspect of the tibial shaft has poor soft tissue protection, and the blood supply to the tibial shaft is also poor.
- Extensive muscle necrosis: There are few collaterals between the three main arteries of the lower leg. Thus a high-energy injury damaging one of the main arteries, often causes complete necrosis of several muscle bellies from the level of knee joint down to the ankle.
- Compartment syndrome: The fascia of the lower leg is tight – even moderate hematomas under the fascia may cause a compartment syndrome. The anterior compartment is especially vulnerable.
- Difficult drainage: There are several spaces between the long muscle bellies where hematomas may escape diagnosis and drainage, and thus form abscesses.

Recommendation

Assess high-energy injuries to the lower leg carefully. Primary amputation should be done on ready indications.

Reasons to do primary amputation: p. 239.

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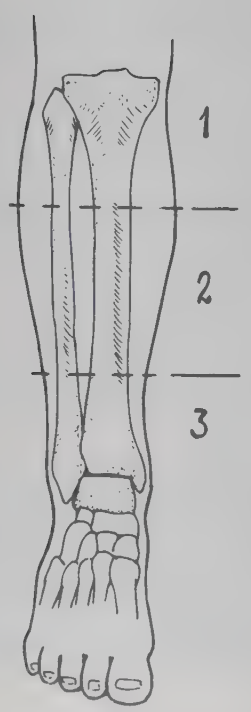
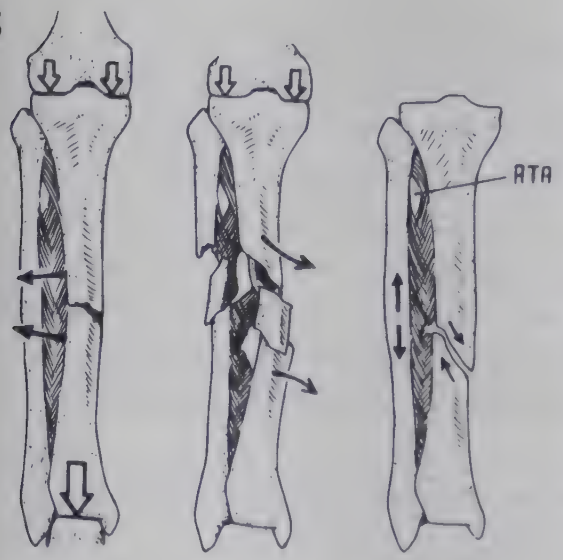


54 The problems in lower leg fractures: Concentrate on the tibia fracture – the tibia carries the weight, fibular fractures are of less importance.

- 1 – Proximal fractures normally heal well. The main problem is joint injury: Does the fracture enter the knee joint? Concentrate on preventing joint infection (p. 220).
- 2 – Tibial shaft fractures are the main problem. Concentrate on careful soft tissue debridement and drainage of deep compartments. Cover the fracture with healthy soft tissue flaps.
- 3 – Distal tibial fractures normally heal well. Reduce the fracture immediately after injury to prevent nerve and vascular damage. If the fracture enters the ankle joint, concentrate on preventing joint infection.

5

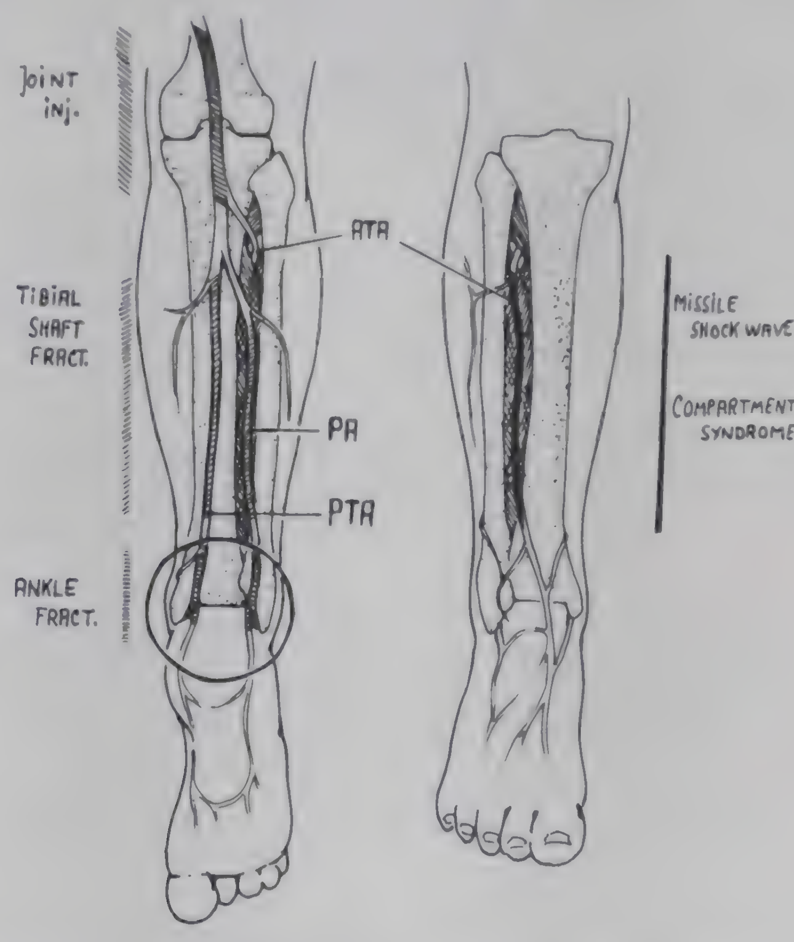


55 Assess the stability of the tibia fracture: Between the tibia and the fibula is a strong fibrous membrane, the interosseous membrane. Through this membrane the undamaged fibula acts as external fixation on the tibial fracture. A comminuted or segmental fracture of the fibula breaks this external fixation on the tibia. Delayed healing: Within weeks there is always some resorption of bone at the fracture site. In isolated fractures of the tibial shaft, the fibula and the interosseous membrane may distract the fracture fragments: Even weight-bearing inside an orthosis will not compress the fracture. In that case the fibula must be cut (fibular osteotomy, ill. 75) to accelerate the fracture healing. Notice the hole in the interosseous membrane for the anterior tibial artery (ATA); where the artery penetrates the membrane it may be damaged directly by fracture fragments, and indirectly by the missile shock wave.

56

56 Anterior-posterior displacement: The strong triceps surae muscle and the anterior tibial muscle tend to displace the distal fragment in the posterior direction. The displacing force is reduced when the knee joint is flexed: Apply plaster casts on unstable fractures with the knee flexed at 90 degr. Also flex the knee under traction management for better fracture alignment.

57



57 Vascular injury – compartment syndrome: The popliteal artery (and vein) splits into three main arteries of the lower leg: two in the posterior fascia compartment, the peroneal artery (PA) and the posterior tibial artery (PTA) – both located close to the bones. And the anterior tibial artery (ATA) passing through the interosseous membrane to enter the anterior compartment. Vascular injury differs at various locations:

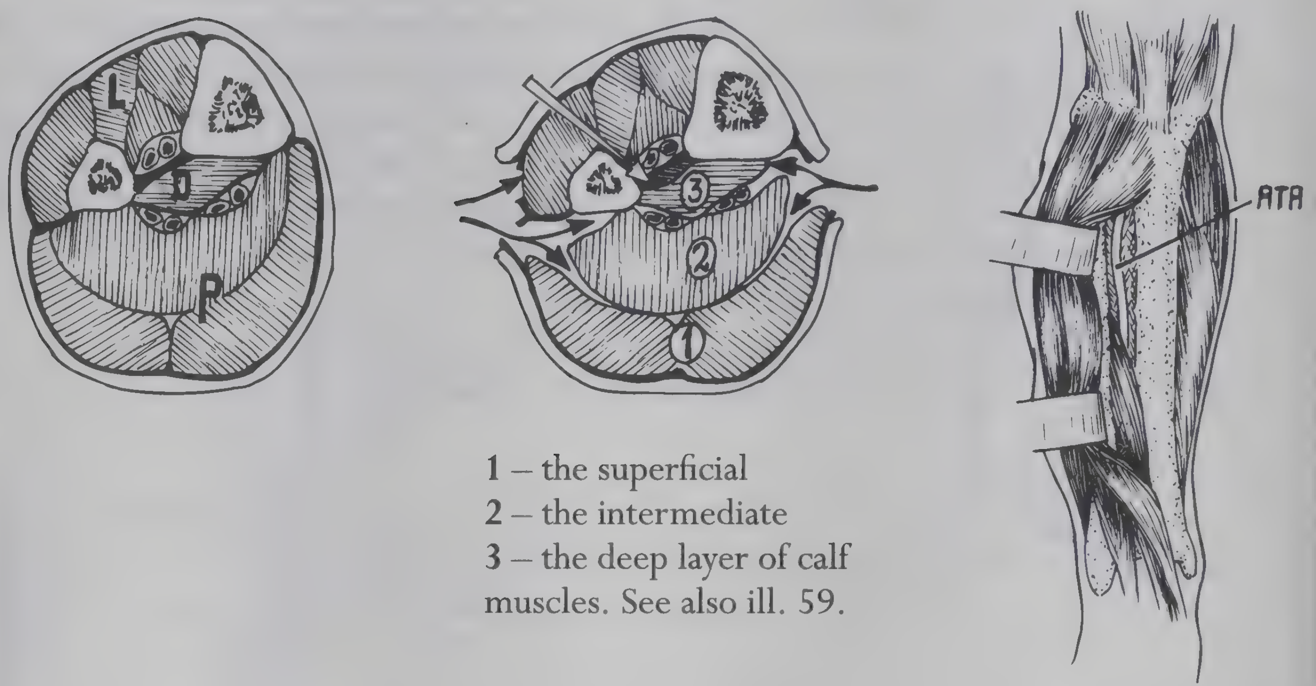
- At the knee joint: Suspect intimal injury to the popliteal artery after high-energy injuries (p. 82 and 531).

- Tibial shaft fractures: Bone fragments may tear the arteries.
- The anterior compartment: High-energy shock wave may cause isolated and total necrosis of the anterior compartment. The necrosis may develop in two ways: (1) Fasciotomy was not done, and the blood supply collapses due to increased compartment pressure. (2) Or the anterior tibial artery is blocked by intima detachment and thrombus at the point where it penetrates the interosseous membrane. **Notice:** The isolated anterior compartment necrosis is seen also in cases where the injury is below ankle level, as injuries from light antipersonnel mines and high-energy bullet wounds through the calcaneus or talus.

Mine injuries: p. 85.

- Ankle fractures: Displaced bone fragments may damage the arteries and nerves located close to the malleolar bones.

58



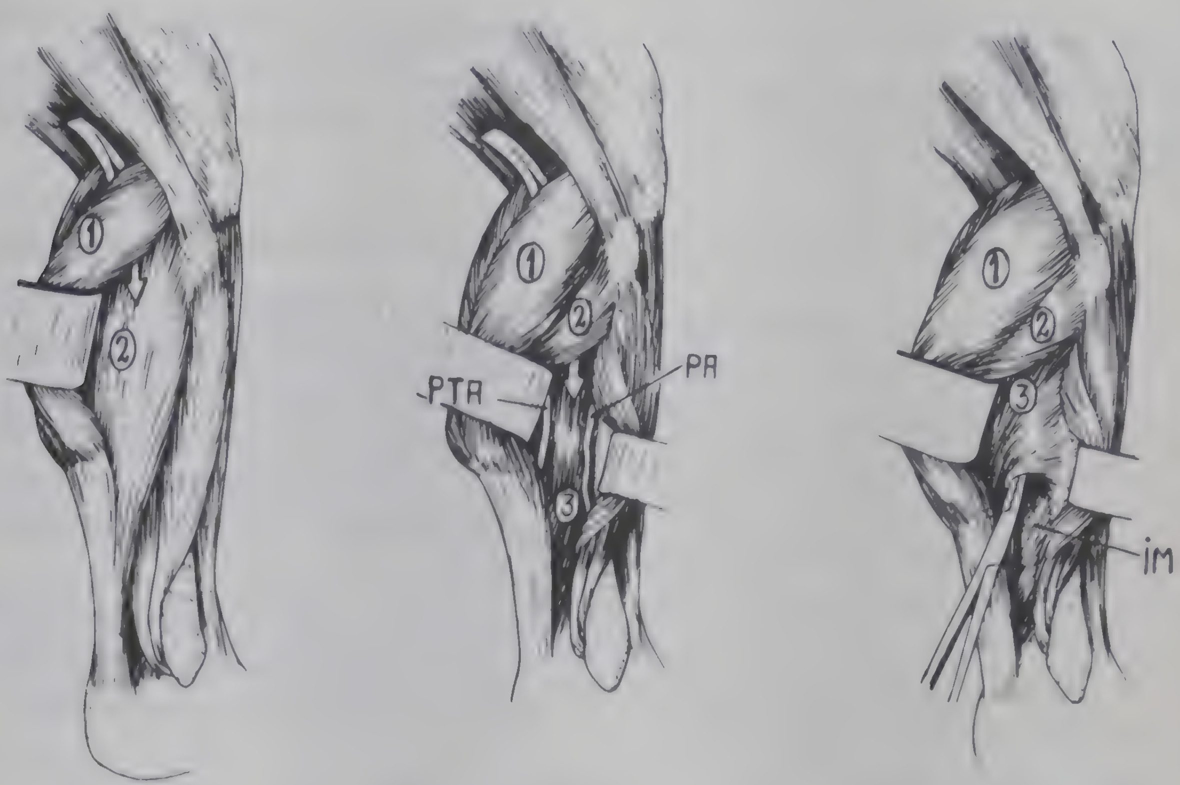
1 – the superficial
2 – the intermediate
3 – the deep layer of calf muscles. See also ill. 59.

58 The fascia compartments of the lower leg: The cross section illustrates the three main fascia compartments.

- **L:** The lateral compartment anterior to the fibula with the anterior tibial artery (ATA) and vein. This compartment is the most vulnerable to compartment syndrome and muscle necrosis.
- **P:** The main posterior compartment with both the posterior tibial artery and vein (medially) and the peroneal artery and vein (laterally).
- **D:** The deep posterior compartment is close to the interosseous membrane. Fracture hematomas often collect inside this small compartment (white arrow).

You may do fasciotomy on all three compartments through an incision lateral to the fibula. For the deep compartment a short fasciotomy to drain the hematoma is sufficient (ill. 59). Isolated fasciotomy and exploration of the anterior compartment is done with an incision lateral to the anterior margin of tibia (black arrow). Double incisions and double drainage (medial and lateral) should always be used in major injuries.

59



59 Other spaces to drain (standard lateral exploratory incision): When the posterior fasciotomy is done, identify and drain the spaces where hematomas normally form.

- Split the superficial (1) and the intermediate layer (2) of the calf muscles by blunt dissection: Hematomas from the popliteal area may collect along the vessels in this space.
- Release the intermediate layer of the calf muscles (2) from its attachment to the fibula and tibia; retract it to enter the space where the two posterior arteries are located (PTA – the posterior tibial artery. PA – the peroneal artery). Note the communication along the vessels from the popliteal area down into this space (white arrow).
- To decompress the deep compartment: Split the fascia over the deep layer of calf muscles (3). To drain fracture hematomas: Retract the deep layer and drain along the interosseous membrane (IM).

60

60 The fascia compartments of the foot do not communicate with the compartments at the lower leg. This cross section through the base of the metatarsals shows the four separate fascia compartments of the foot:

- The medial compartment contains the flexor muscles for the 1st toe.
- The lateral compartment contains the flexors for the 5th toe.
- Between them, the central compartment containing the flexor muscles for the 2nd-4th toes.
- The dorsal compartment between the metatarsal bones that contains the interosseous muscles and the nerves and vessels for the toes.

All four compartments should be decompressed by fasciotomies in mine cases, high-energy fractures and crush injuries. In the medial compartment the edema and muscle necrosis may be especially extensive. The first sign of a foot compartment problem is deep plantar pain on dorsal motion of the toes, especially the 1st toe.

Also see diagnostic nerve function test at the upper limb: p. 487.

Nerve function tests indicate vascular injury

The three main nerves follow the main arteries in the lower leg. Loss of function in one nerve thus indicates probable injury also to the artery following that nerve:

- The two peroneal nerves and the anterior tibial artery: All are located deep inside the anterior fascia compartment. They may be damaged by bone fragments in comminuted fractures, and by compartment syndrome in the anterior compartment. The nerves supply the skin on the dorsal side of the foot. Do nerve function tests as routine: p. 120.
- The tibial nerve and the posterior tibial artery: Both are located deep inside the posterior compartment. Not only shaft fractures and posterior compartment syndrome, but ankle fractures may also damage the tibial artery and nerve:
  Displaced fracture at the medial malleolus may tear or stretch (intimal rupture) the vessel. As the nerve supplies the plantar structures of the foot, sensory loss indicates vascular injury.

Preparations for surgery

- Reduce fractures immediately, at best in the field. Do not delay the reduction if surgery is delayed. Early reduction may prevent vascular injury and compartment syndrome, and reduce the bleeding. Rough reduction is done by manual traction along the axis of the limb (i.v. ketamine or hematoma anesthesia, p. 152).
- Immediately on admission: Wash thoroughly and instill dilute soap solution in open missile fractures and other deep wounds.
- Cases with risk of compartment syndrome: Do not delay the fasciotomy if surgery is delayed – not even for 30 minutes. Decompress the anterior and superficial posterior compartments in the field before the evacuation starts, or immediately on admission to the clinic.

Indications for fasciotomy: p. 177.

On the operating table

- Wash a wide operating field – including the popliteal area (artery exploration and control) and the foot (monitoring the distal circulation throughout the operation).
- Open fractures: Apply traction before surgery for better exploration (Steinmann pin through the tibia end or the calcaneus).
- Apply a deflated BP-cuff at the lower thigh in case of difficult-to-control bleeding during surgery.

Calcaneus traction: p. 212.

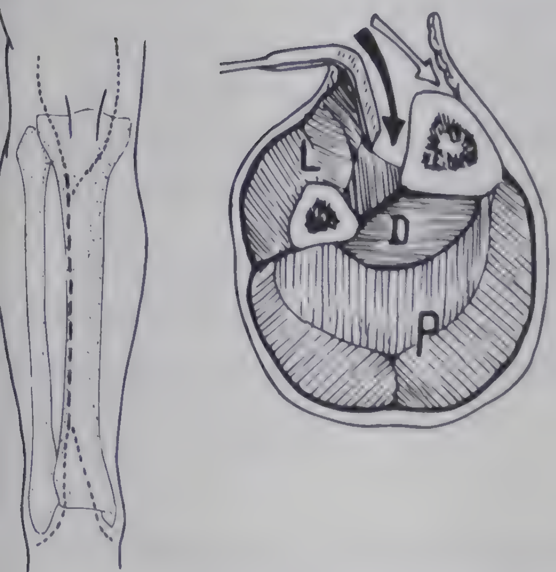
Anesthesia

- Both spinal and ketamine anesthesia may be used. As lower leg injuries normally bleed less, there are seldom problems to use spinal anesthesia after volume pre-load. The spinal anesthesia also makes debridement and reduction of fractures easier.
- I.v. anesthesia may be used in secondary surgery on lower leg and foot cases. For debridement and primary surgery the bloodless field makes the assessment of tissue viability difficult.
- Nerve block anesthesia at the ankle or at the base of the toes is useful; you may supplement it with low-dose ketamine anesthesia.

Do not use bupivacaine for intraosseous anesthesia due to side effects on the heart.

- Intraosseous anesthesia: Slow injection of lidocaine with adrenaline into the cancellous bone of calcaneus may be useful as a supplement to infiltration anesthesia.

61



Exploration and fasciotomy

61 **Standard incisions for exploration – the anterior incision:** Both anterior fasciotomy and exploration of tibia fractures may be done by this incision. But **notice:** As the medial standard incision is less traumatic to the soft tissues, it should be the standard incision used to explore tibial fractures. Make the skin and fascia incision at minimum 3 cm lateral to the edge of the tibia. You may extend the incision to one of the standard incisions for exploration of the knee joint. Never split the skin over the medial surface of tibia: That incision will not heal. Release the muscles from the lateral surface of tibia and expose the interosseous membrane with the anterior tibial artery. In high-energy hits you may find complete necrosis of all muscles inside the anterior compartments – even if the posterior compartment (P) is not injured: In that case, excise all necrotic muscle without compromise, leave the incisions wide open, use a lateral gastrocnemius muscle flap for closure.

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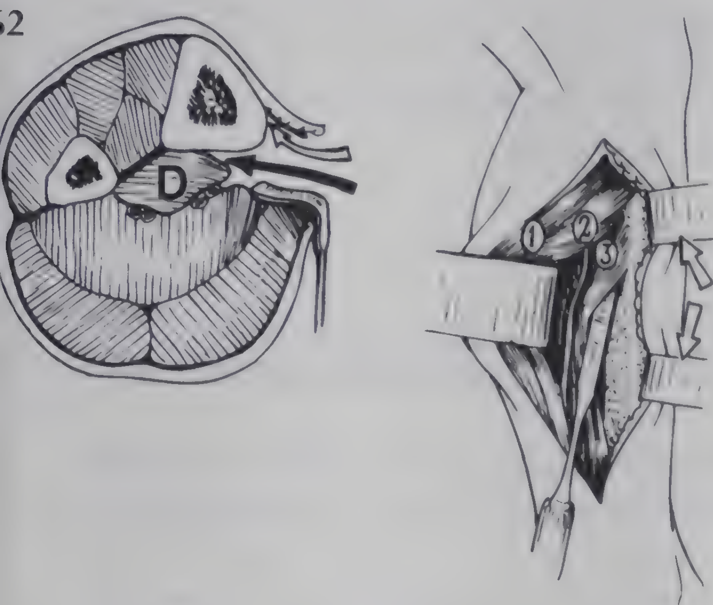

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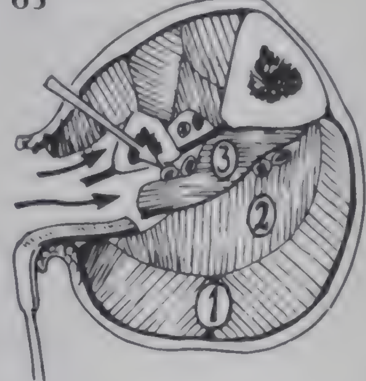

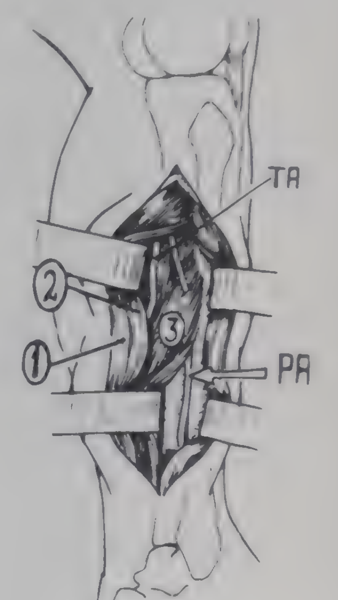

Compare with ill. 59 on p. 541.

62 **The medial exploratory incision:** This is the standard incision to explore and manage tibia fractures. But for simple fasciotomy of the leg compartments the lateral incision is better (ill. 63).

Make the skin and fascia incision at least 3 cm behind the posterior edge of the tibia – posterior to the saphenous vein. You may extend it behind the medial malleolus of the ankle, to the ankle, or into the popliteal area to manage vascular injuries. Release the intermediate layer of the calf muscle (2) from its attachment to the tibia, retract it together with the gastrocnemius muscle (1), and enter the space next to the deep compartment (D): Identify and explore the two posterior arteries. To expose the posterior surface of the tibia, you also have to release the long toe extensors (3) from the tibia. Note the arrows: Be careful not to damage the soft tissues at the posterior edge of the tibia with retractors.

63 **The lateral exploratory incision** is the standard incision for all compartment fasciotomy of the lower leg. The skin incision is 3 cm behind the fibula. You may extend it behind the lateral malleolus into the foot. **Notice:** Beware of the peroneal nerve as it crosses the neck of the fibula and enters the anterior compartment below the knee joint (ill. 41). **Notice:** As the peroneal artery (PA) enters the deep compartment mid-calf, decompression and drainage of the deep compartment are most effective when done below mid-calf.

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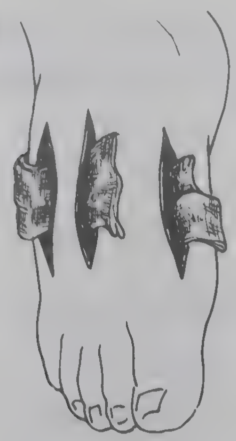


Also see ill. 60.

64 **Fasciotomy of the foot** is always done from the dorsum of the foot. By three separate incisions all four compartments are decompressed and drained. The fasciotomy incisions are closed by split-skin grafts within one week after the surgery.

- The medial incision is done at the lower edge of the first metatarsal through the skin and the thick plantar fascia. The spaces between the muscle bellies are opened by finger dissection. For full exploration of the medial and central compartments: Extend the fasciotomy incision towards the medial malleolus.
- The lateral incision is done from the dorsal side between the 4th and 5th metatarsals. By blunt dissection (artery forceps) close to the the 5th metatarsal, the wall of the lateral compartment under the bone is split and the compartment opened.
- The central incision is done between the 2nd and the 3rd metatarsals. By blunt dissection deep to the metatarsals the central compartment is entered. Make sure that the forceps split all muscles of the deep central compartment down to the plantar fascia.

Vascular surgery: p. 185.

Vascular injury

The popliteal artery should be reconstructed after injury (p. 188). But time-consuming reconstructions of the three lower leg arteries have no place in wartime surgery. The main blood supply to the foot is carried by the tibial artery. In young patients the limb may survive only on the tibial artery, provided the period of circulatory shock was short. Combined tibial nerve-tibial artery injury normally indicates primary amputation.

Fracture management

The main problem: delayed healing and infection in tibial shaft fractures

To cover the fracture with well-circulated soft tissue is the most important measure to prevent fracture infection. Consider a two-step strategy in high-energy cases:

- During primary surgery concentrate on the soft tissues: fasciotomy, debridement, soft tissue flap mobilization, and drainage. Exact reduction of the fracture is of less importance: Arrange temporary fixation – Trueta plaster cast or traction.
- Within 1-3 weeks after the injury healthy soft tissues cover the fracture. If necessary re-explore the fracture to debride and reduce the fracture. Arrange for permanent fixation – plaster cast, external fixation or traction.

Muscle-skin flaps: p. 201.

Soft tissue management – cover the fracture

- Alternative one – primary soft tissue flap: When the debridement is done, raise a broad-based muscle-skin flap from the posterior/medial side of the calf and suture it to the fracture site. Leave the bed from which the flap was raised open with saline-wet dressing for five days – then close it with free skin grafts.
- Alternative two – primary Trueta plaster cast and secondary grafting: When

the debridement is done, insert gauze drains in fasciotomies and to the fracture field, and apply a Trueta standard lower leg plaster cast (ill. 65) directly onto the fasciotomies and the wound. Split the cast to prevent compartment syndrome. Remove the cast after 4-6 weeks. If the primary debridement was well done, you will find the fasciotomies and the wound filled with healthy granulations: Do skin grafting.

- Alternative three – drill cortex and graft directly onto bone: If flaps or granulations did not cover the fracture, you may develop granulation on naked bone by drilling several small holes through the cortical bone. Under saline-wet dressing, granulations will develop through the drill-holes within a week. Then do split skin grafting directly onto the bone. This method is suitable for the anterior medial surface of tibia.

Fracture management – alternative strategies

[T]he Trueta method of fracture [m]anagement: p. 208.

- The proximal end of tibia: Dynamic traction is done during the period of soft tissue management, then plaster cast. Or primary plaster cast if the soft tissue injury is not so extensive.
- The shaft of tibia: External fixation apparatus is the best method where there is extensive soft tissue injury; when the soft tissues have healed, plaster cast is applied. Alternative: static traction during the period of soft tissue management (distal tibia or calcaneus pin), then plaster cast. Alternative where there is less soft tissue loss: primary Trueta plaster cast with bone pins.
- The distal third of tibia: Primary cast management is the alternative of choice. **Notice:** Calcaneus traction on distal open fractures carries high risk of calcaneal osteomyelitis as the traction pin is located close to the wound field.

Warning: Long-term traction management is a hazard

[T]he traction management in detail: [p]. 211.

The complications are well known: delayed healing, secondary infections and deteriorating general condition of the patient. Particularly in the tibial shaft fractures where the bone nutrition is generally poor due to anatomical reasons, traction management should be used with care:

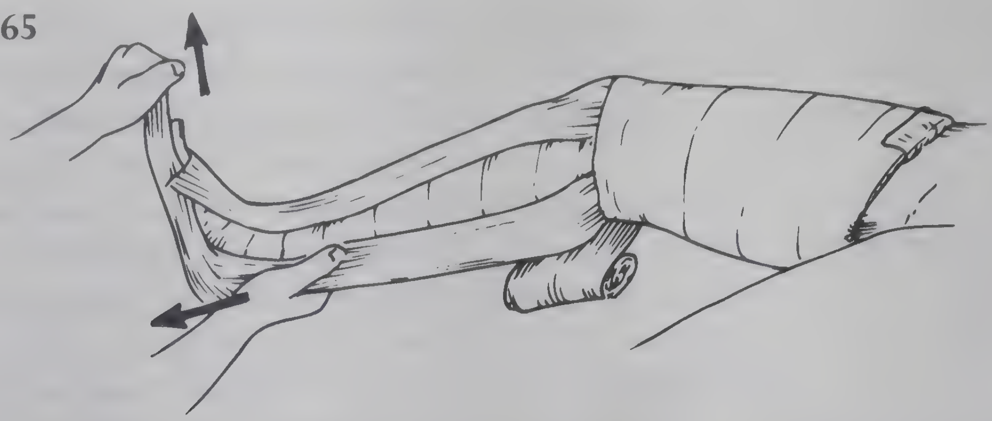
- Apply traction only if the soft tissue injuries need monitoring, dressing and repeated surgery – and you have no external fixation apparatus.
- Use traction management only during the period of soft tissue managment: Do skin grafting, apply cast and mobilize the patient as soon as the soft tissues have healed and the fracture is closed.
- If the healing is slow, do not extend the traction management – but do surgery: Redebride the fracture and the soft tissues. Mobilize healthy soft tissues onto the fracture. Consider amputation.

[T]he Sarmiento cast: p. 206.
[L]ower leg orthosis: p. 215.

Optimal timetable

- Within four weeks after the injury: The soft tissues should have healed and the fracture closed – apply cast.
- 4-6 weeks after the injury: Callus develops – start careful weight-bearing.
- 6-10 weeks after the injury: Apply a Sarmiento plaster cast or an orthosis to accelerate healing.

65

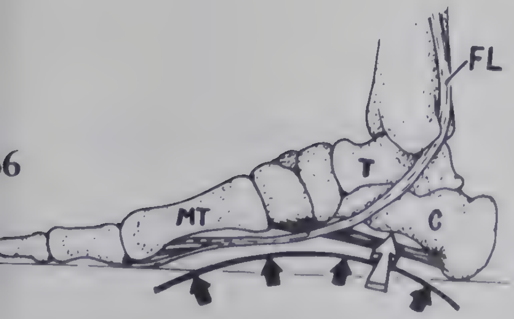


65 The standard lower leg plaster cast should reach from below the trochanter to the base of the toes. Outside a one-layer circular plaster, apply two long slabs. Fix them with turns of 15 cm rolls. **Notice some details:**
- Do not pad too much, especially at the fracture level, as padding makes the cast support the fracture less (p. 204).
- You need two assistants: One should maintain traction on the foot, the ankle joint in neutral position. The other supports the thigh, the knee joint 15-30 degr. flexed.
- Mold the cast well to fit the contour of the leg in each section, see ill. 48.
- Mold the distal cast to support the arches of the foot.

Missile fractures at the ankle

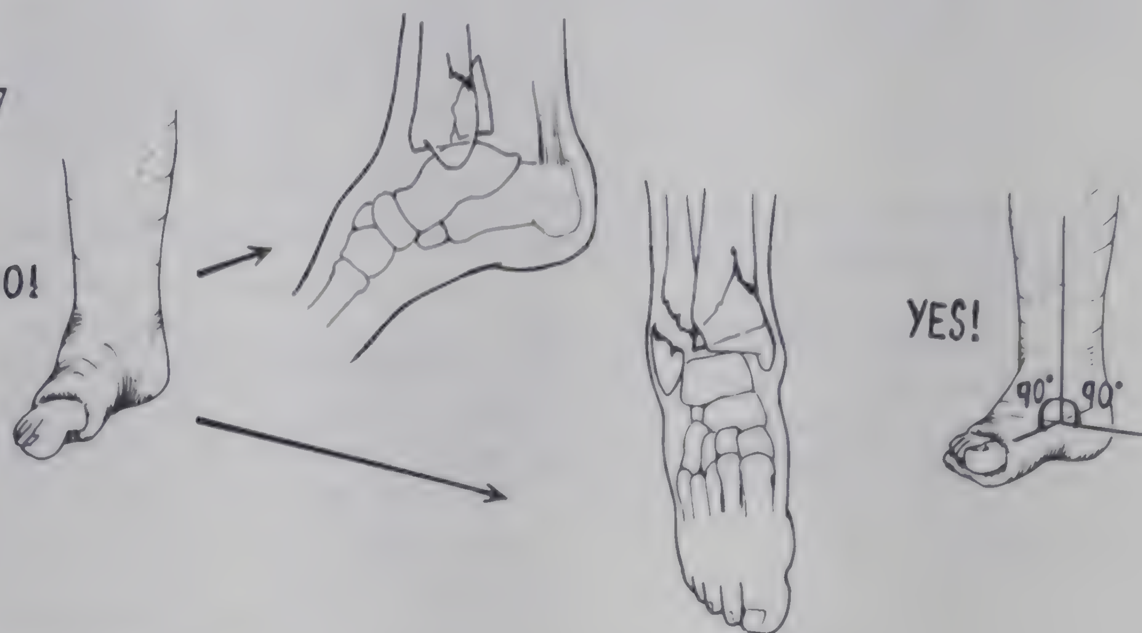
Fractures of talus and calcaneus – particular problems of healing: ill. 68.

As the bone and soft tissues at the ankle are well supplied from a rich network of collateral blood vessels, injuries generally heal well. The main points of management:
- Explore the lower leg and the foot as a routine: A high-energy hit to the ankle area may cause shock-wave injury with artery obstruction and muscle necrosis up to the level of the knee joint. The anterior lower leg compartment and the medial foot compartment are at special risk: Fasciotomy may help the fracture healing.
- Close the fracture with healthy soft tissue: Either use primary rotation full thickness skin flaps, or primary Trueta plaster and secondary skin grafting.
- The fracture management: Bone fragments without soft tissue attachment should be removed. Minor deranged fragments of the articular surface of tibia or talus are also removed, or else they may cause steps of the articular surface and secondary progressive joint pain. Save the structure of the malleolar bones – they are essential to the stability of the ankle joint.
- Primary amputation depends mainly on the soft tissue state: If the ankle joint is extensively deranged, still apply a conservative strategy if the vascular and nerve function of the foot is good – an ankle with some joint function is better than nothing. Extensive loss of soft tissues and nerve function normally indicates amputation.



66 The biomechanics of the foot: The two arches of the foot carry the total body weight, and are essential to walking. Save the main structures during debridements and resections; support them during plaster cast immobilization. The longitudinal arch of the foot carries the total body weight. It consists of the calcaneus (C), talus (T) and the metatarsal bones (MT). The flexor tendons (FL) on the medial side, the peroneus tendon on the lateral side together and the short plantar muscles suspend the arch. **Notice** that the space close to the calcaneus under the fat pad of the heel (white arrow) is a common site for abscesses to form in open fractures of the heel area.

67



67 Immobilization of the ankle: An incorrect position may cause permanent damage to the ankle/foot – and displace ankle joint fractures. Immobilized under flexion, the load through the tibia hits the talus off center: A painful ankle and posterior fragment displacement will be the result. Immobilized under pronation, fractures of the lateral malleolus will displace and the ankle will contract in equinus malposition.

68 A particular problem: fractures of the calcaneus and talus. High-energy fractures in these bones tend to develop a low-grade osteomyelitis: The cancellous bone becomes soft and waxy, the suppuration from the wound channel of the bone persists – even if the fracture is well debrided and soft tissues healthy and without infection. A similar state of calcaneus bone necrosis may develop after high-temperature deep burns to the foot. In our experience, early bone grafting, soft tissue rotation flap, and application of a Trueta plaster at the time of primary surgery are the management of choice for these injuries:

Debride deliberately the fractured cancellous bone (orthopedic curet) until there is fresh bleeding from the bone. Small chips of bone (chiseled from the fibula or the pelvic wing) fill up the wound track inside the calcaneus. Debride the soft tissues and mobilize a local full thickness skin flap. Cover the donor site with a split-skin graft. Drain the fracture into a plaster cast and mobilize the patient. Expect suppuration for some weeks; another debridement of the fracture is of no use. If the fracture is still suppurating after two months, excise the posterior fragment or the whole calcaneus; suture the Achilles tendon to the plantar fascia.

Types of amputation

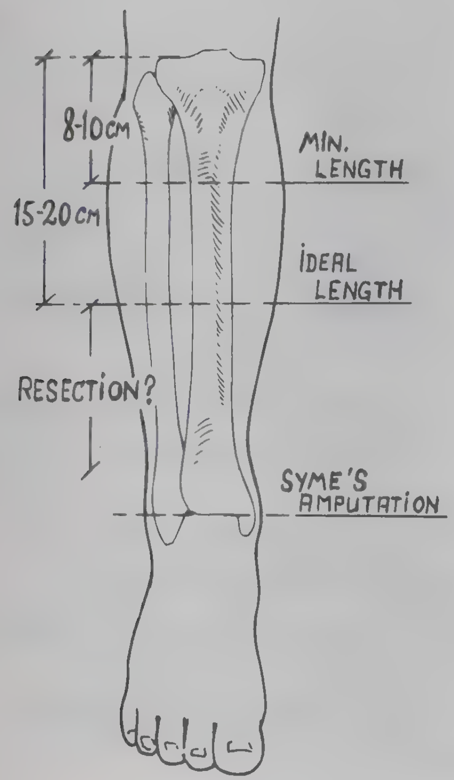
Reasons to do primary amputation: p. 239.

Operation time, hypothermia and coagulation system failure: p. 130.

Below-knee injuries – there are three reasons why primary amputation should be done on ready indications:

- Unstable multi-injury patients: The veins of the lower leg are where thrombus formation starts. If leg-saving surgery means repeated operations, extensive blood loss and transfusions, and long-term immobilization in bed – primary amputation may be life saving.
- A multi-injured leg/mine case: Carrying out extensive primary surgery in order to avoid amputation and save the lower leg or foot, will cause hypothermia and may prolong the period of leg hypoperfusion. This is a risk also to the proximal parts of the leg: You may have to do secondary amputation at a higher level, lose the limb – or even lose the patient.
- The below-knee prosthesis functions well and is easy to produce.

69



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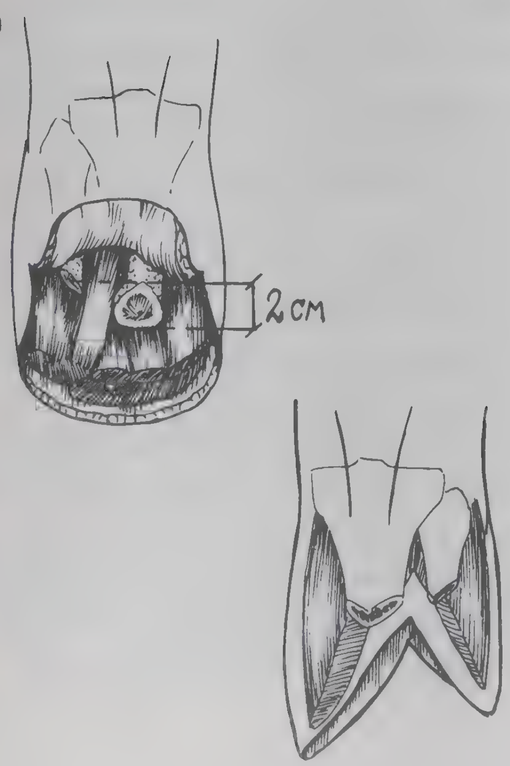


69 Amputation levels: The stumps sustain a large weight load – design stumps with good soft tissue and skin protection. Better perform the amputation at a level where the soft tissues are sound, rather than save some cm of bone length and get a vulnerable and painful amputation stump. But note the critical length: The tibia stump should be at least 8 cm long to control a hinged prosthesis. The ideal length is 15-20 cm. If you cannot amputate through the ankle joint (Syme's amputation is safe, and very useful in areas with no prosthesis service), there is no reason to amputate at the lower tibia: The soft tissue protection for the bone is poor, the stump will hurt under weight load, and you risk complications and reamputation.

70 The lower leg amputation – the soft tissue injury decides the flap design

- Anterior-posterior flaps: The posterior flap is long as its circulation is better. It provides good soft tissue padding of the bone stump. Also the suture line when you close the stump will be located in front of the weight-bearing tibia bone stump.
- Medial-lateral flaps: Design the medial flap as the longer one to cover the tibia bone stump. Locate the suture line off the weight-bearing end of tibia.

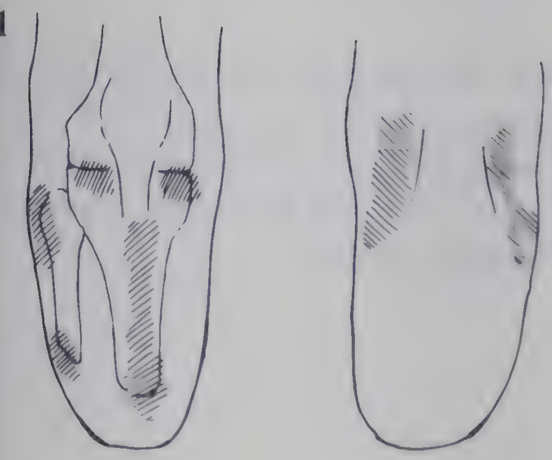
The procedure: Do not dissect the soft tissues separately, but make an all-in-one posterior flap that consists of skin, fascia and muscles. To do that, the dissection of the posterior (or the medial) flap is done from inside out:

- Mark the flaps on the skin with marker pen.
- Isolate the anterior skin-fascia flap, identify and control the anterior tibial artery (ill. 58), and amputate through the anterior compartment.
- Saw off the tibia, and the fibula 1-2 cm proximal to the tibia stump.
- Then identify and control the posterior vessels: the posterior tibial artery close to the tibia, and the peroneal artery with two veins behind the fibula.
- Now isolate the posterior soft tissue flap from inside out: Cut the inner and intermediate muscles (soleus) flush with the tibia amputation to thin the flap. Cut the superficial muscle (gastrocnemius) at level with the fascia-skin incision.
- Extend the incisions towards the knee joint as fasciotomies, and explore the

muscles carefully: Necrotic patches and necrotic muscle bellies are excised – and the incisions left open for decompression.

- Drain with gauze and apply a Trueta plaster cast to mid-thigh, the knee joint flexed at 10-20 degrees, to prevent flexion contracture at the knee.

71

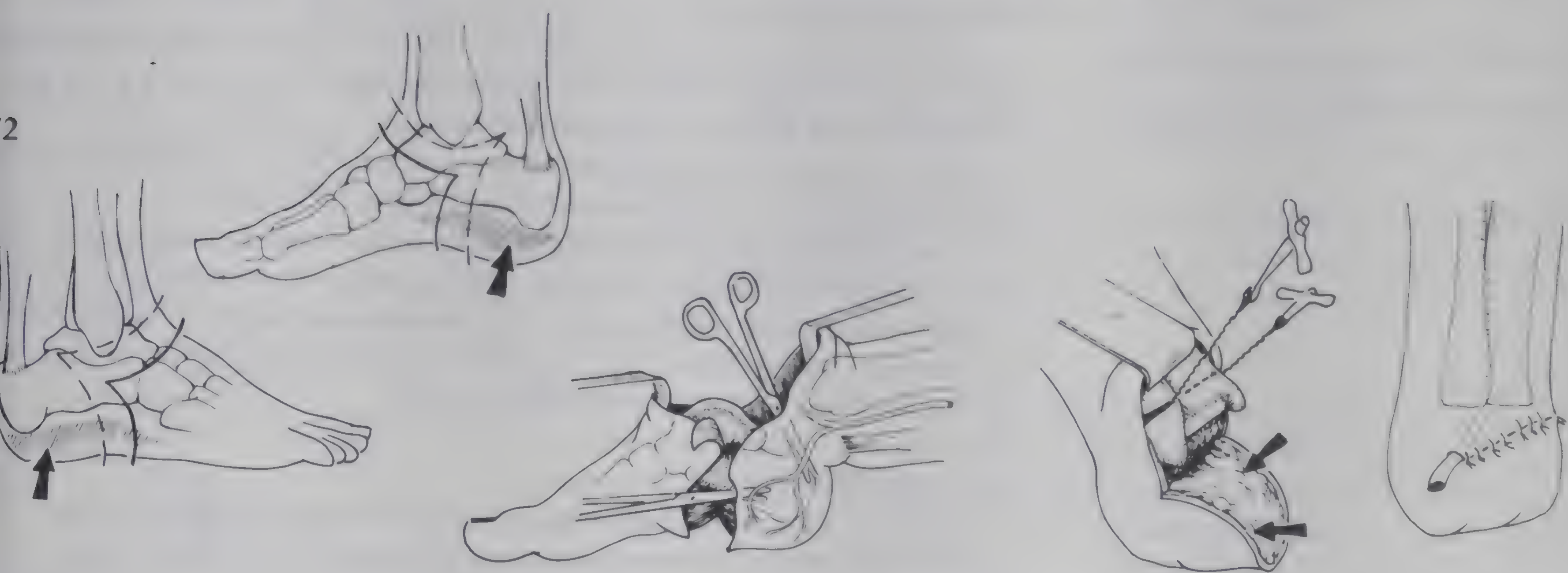


Temporary training prosthesis:
. 244.

71 Stump design and stump closure: The closure is done 5-10 days after the amputation: We do not use myoplasty in lower leg amputations. The thick muscle-fascia-skin posterior flap is sutured fascia-to-fascia to the anterior flap. There are some points to consider for a good stump:

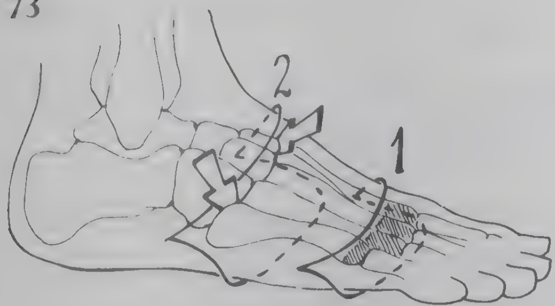
- The shaded areas illustrate where the soft tissues of the stump are vulnerable to pressure inside the prosthesis holster: Trim the bone ends nicely. Apply local anesthesia nerve block along the main nerves. Handle with care the skin along the anterior edge of tibia. Design the flap size so as not to suture the flaps under tension.
- Do not make a clumsy stump: You may thin the flap more by cutting more of the soleus muscle at the flap base. And make a wedge-resection in the gastrocnemius in the midline.
- Suture the flaps over double-tube drains, and again apply plaster cast to prevent knee joint flexion contracture. Pad the cast well over the bony prominences. Let the cast reach the groin: Fix a training prosthesis to the cast and start walking within five days after stump closure under effective analgesia.

2



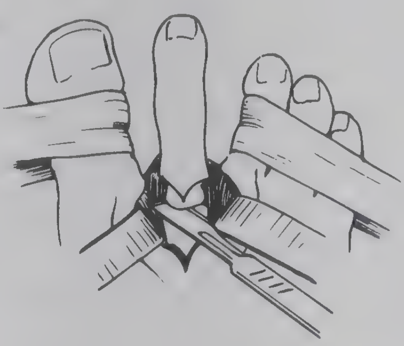
72 Syme's amputation for ankle and foot injuries: The Syme's stump is well padded by soft tissues, it tolerates weight-bearing well, and is a good alternative where there is no prosthesis service. A condition for a good Syme's stump is a heel fat pad without major damage (black arrows). The wounds decide the flap design (dotted lines). The incision is carried directly through the skin, subcutaneous fat, fascia and tendons. The calcaneus bone is released by sharp dissection close to the bone to protect the vascular supply to the heel pad. The tibia and fibula are cut just above the ankle joint, and the bone edges trimmed with a rasp. After 5-10 days the stump is clean and without infection: The heel flap is then trimmed and sutured to the fascia and skin in front.

73



73 Mid-foot amputation for foot injuries: If the injury is too extensive fo
a ray amputation of one or two metatarsals (p. 241):
- Either amputate through the metatarsal shafts – 1.
- Or do disarticulation through the tarso-metatarsal joints – 2. Design long an
thick all-in-one plantar flaps of skin, fascia and muscles.

74



74 Toe amputation is done throug any joint of the toe, or through the metatarsal bone as ray amputation. Take care to cut the nerves as proximal as possible.

Complications of limb injury and surgery

Complications of plaster management

Prevention and management of complications: p. 206.

For drainage and fracture immobilization, this manual recommends circular plaster casts applied at the time of primary surgery. The method is effective and safe only when precautions are known: The risk of compartment problems is high in lower leg plaster casts. The venous drainage of the lower leg is a special problem, and all primary casts should be split – even if the leg is not very swollen at the time of cast application. As a routine, illustrated information on how to prevent plaster complications should follow each patient.

The exudation from extensive thigh and leg injuries may be considerable. If you use the Trueta plaster method, the staining and smell from the plaster may be a problem. Explain to your patient that the more staining there is, the better the drainage – and the better the prognosis. If you drape the plaster in cloth bags, the smell is reduced to an acceptable level.

Soft tissue infection
- Do not delay the re-exploration: In most cases secondary infection is the result of poor primary debridement and/or drainage. Reoperate without delay with wide exploratory incisions; excise the necrosis left over from the primary surgery. Hesitation to do another debridement may put both limb and life at risk.
- Specially explore the anterior lower leg compartment: The clinical signs of complete compartment necrosis may be few – warm skin over a tender anterior compartment indicates exploration.
- Necrotizing fasciitis is a condition seen sometimes after extensive crush injuries of the lower limb: One week after injury, widespread necrosis of the skin, subcutaneous tissues and fascia develops very rapidly and affects wide wound fields much like a deep burn wound. In most cases the fasciitis is caused by streptococcal strains. The management is aggressive debridement with excision of all necrotic skin, subcutaneous fat and fascia, followed by saline or potassium permanganate baths and secondary skin grafting. In cases

The bacteriology of necrotizing infections: p. 649.

where the infection and necrosis are quite resistant to treatment, amputation must be done.

Arthritis

The reason is poor primary surgery – debris, dirt, foreign bodies or necrotic tissues were left inside the joint. Or the joint was infected through an open fracture, missed at the time of primary surgery. Reoperate without delay with wide exploration of the joint and resection of all necrotic bone fragments. If you are able to close the joint after redebridement is done, continuous antibiotic washing of the joint is done. If not, do amputation/disarticulation. Or leave the joint wide open, and do secondary arthrodesis.

Fracture infection

The management is surgical, there is no wait-and-see: Re-explore the fracture, and remove all necrotic bone fragments without compromise. Most important: Clean up the soft tissues and close the fracture by healthy muscle or muscle-skin flaps. If this is not possible, the case is probably one for amputation.

Delayed healing of fractures

Despite good soft tissue management, no evident local infection and early weight-bearing, some tibial shaft fractures heal very slowly: There are no signs of bony union in X-rays three months after the injury, and by clinical testing the fracture remains just "elastic" for months. Then consider three possible reasons:

- Missed infection? A low-grade osteomyelitis may prevent bony union.
- Vascular injury? A missed vascular injury may cause poor fracture nutrition and delayed healing.
- Poor nutrition – poor general condition? In patients immobilized for weeks in a catabolic state, fractures heal slowly/do not heal even under optimal local conditions. Having the patient out of bed, and high-energy nutrition are the only effective measures.

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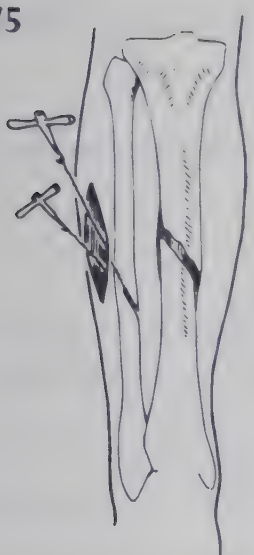


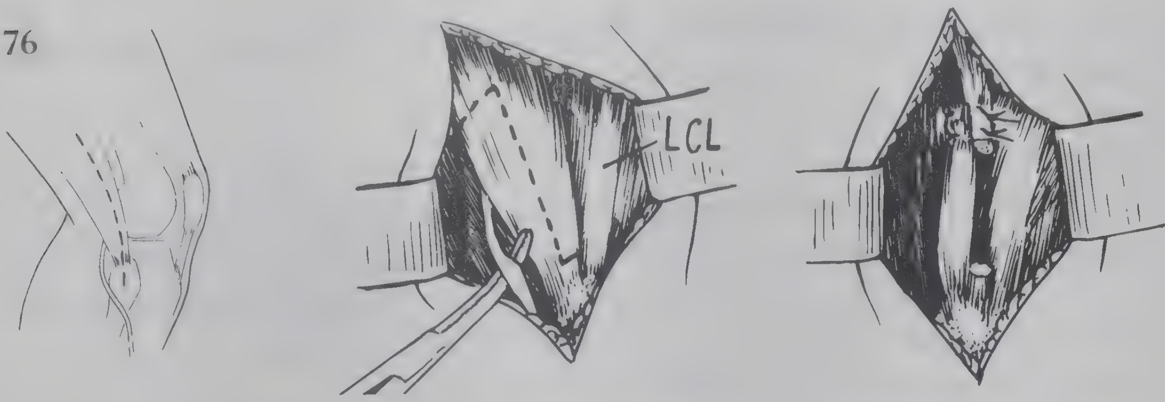
75 Osteotomy of the fibula and weight-bearing accelerate healing
After bone resorption in the fracture line, the uninjured fibula distracts the fracture fragments. Do oblique fibular osteotomy (chisel or Gigli saw) and remove a 1-cm long segment of the fibula. Then apply a Sarmiento plaster cast or orthosis, and tell the patient to load the fracture close to the pain limit. He may have to wear the orthosis for one year, but sooner or later the fracture will heal.

Scarring and contractures

Excessive scarring with contracture of joints will interfere with the rehabilitation. Contracted scars of the skin and subcutaneous tissue are managed with Z-plasty, or scar excision with skin grafting at an early stage. You may try to break contractures of the joints by manipulation of the joint under ketamine or spinal anesthesia – if the manipulation is done soon after the injury. If the mobilization is successful, the joint will contract again if it is not moved 4-6 times a day for 2-3 weeks under effective analgesia.

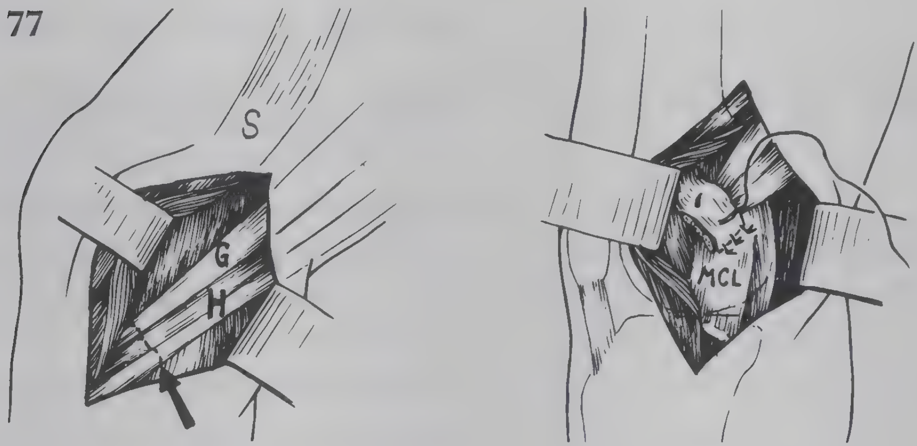
Management of hip joint contractures: p. 480.

76



76 Knee joint contracture – lateral tenotomy: Secondary tendon contractures are managed by tenotomy. Intensive active exercises and passive movements of the joint are necessary to prevent recontracture. The lateral tenotomy is done through a short skin incision posterior to the lateral collateral ligament of the knee (LCL). **Notice:** The peroneal nerve is located close to the skin – identify and isolate it. Do a Z-plasty (dotted line) on the lateral hamstring tendon. The elongation of the tendon should be about 4 cm.

77



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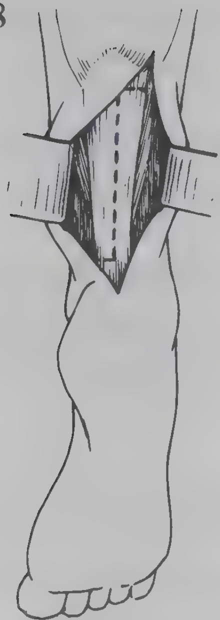


77 The medial tenotomy at the knee: The sartorius muscle (S) is retracted forwards, and the tendons cut close to their attachment (G – the gracilis tendon, H – the medial hamstring tendons). Raise an anteriorly based flap of the periosteum at the femur condyle, and suture the tendons under this flap. MCL – the medial collateral ligament of the knee.

78 Z-plasty elongation of the Achilles tendon is done through a skin incision lateral to the tendon.

Phantom pain and neuroma problems: p. 243.

Cross leg flaps: p. 257.

Poor amputation stumps

The lower leg amputation stumps should be well designed to be able to take the weight load and control the prosthesis. If the stump is clumsy or the amputation level is inconvenient for prosthesis adaptation, better do a secondary elective amputation and revise the stump. Localized chronic skin sores and minor areas with poor soft tissue padding are managed by excision and full thickness skin flaps. Major soft tissue problems in stumps of critical length can be managed by cross leg flaps.

79

79 Excision and sliding graft: The actual skin area is excised, and a broad flap carefully raised from the fascia. The flap is mobilized for direct suture to the excised area. Unlike the free skin graft, the sliding graft contains sensory nerves.

Points to note – Chapter 40

Learn the clinical examination
- to find out how large is the burn: p. 557
- to find out how deep is the burn: p. 558
- not to miss inhalation injuries: p. 558

Learn the triage of wartime burns
- study p. 561-563
- burns combined with other injuries: p. 161

Train in using the Parkland formula to plan the fluid therapy of burns: p. 559
- study the Burn Case Chart: p. 566

Know how to set up a feeding program in major burns: p. 560 and 603
- study the teaching case: p. 567

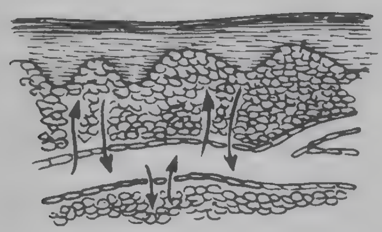
Learn the closed burn wound management
- study p. 569
- know the common burn creams: p. 570
- study the special problems of skin grafting on burns: p. 571 and 573
- train in split-skin grafting: p. 252

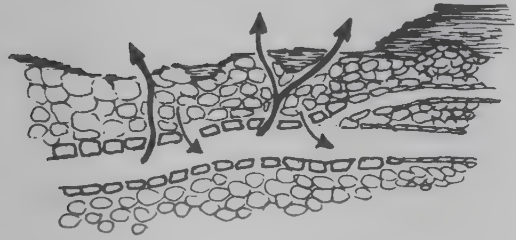
40 Burns

Physiology of burn injury

Burns cause
- loss of fluid from the circulation → tissue hypoperfusion
- increased metabolism until all burn wounds are closed
- dysfunction of the immune system → high risk of secondary infections

Burn cases make a heavy load on the clinic
- Intensive and long-term fluid therapy
- Intensive and long-term high-energy nutrition
- Tissue hypoperfusion and immune dysfunction also complicate associated injuries





The heat exposure affects the total body physiology

- **Tissue edema and loss of fluid after burn injury**
  The normal capillary permeability: There is a balance of fluid, protein and electrolytes on both sides of the vascular wall. After burn injury, the permeability of the capillaries is changed and protein-rich fluid is lost through the capillary wall. Also in non-injured tissue the capillaries leak: The edema becomes general. Within 12-48 hours postburn, the capillary permeability is gradually restored to normal. The skin acts as a membrane preventing extensive evaporation of fluid from the body. Evaporation and exudation through injured skin add to the loss of fluid.
- **Organ hypoperfusion causes organ failure:** Loss of fluid increases the risk of septicemia and secondary organ failure – the greater the loss, the longer the patient is hypovolemic.

Secondary organ failure: p. 588-596.

- **Hypothermia causes circulatory and coagulation system failure:** Temperature is lost through large burn wounds – by radiation, evaporation and loss of warm body fluids. High volumes of infusion further add to the low body-core temperature often seen in major burn cases.

Hypothermia and coagulation failure: p. 131.

- **Immune system dysfunction:** Skin burns affect the body's immune system. Wounded skin barrier and poor activity of the body immune system cause increased risk of burn wound infection, secondary infection of associated injuries, and septicemia.
- **Increased metabolism:** The first day after the injury the metabolism is slightly depressed. Thereafter it is gradually raised, and a state of hypermetabolism is fully established one week after the injury. The hypermetabolism persists until the burn wounds are closed. The degree of hypermetabolism is proportional to the burn area. Assume a 100% increase in the metabolic rate in cases with burns exceeding 40% of the total body surface area.

Calculate needs for nutrition after injury and surgery: p. 602.

- **Burn "fever":** Due to the hypermetabolism, the regulation of body temperature is adjusted. The "normal " body temperature in a major burn case is around 38 degr.C, that is, fever does not necessarily indicate infection.
- **The gastro-intestinal function** is decreased for some days after injury, and a state of paralytic ileus with vomiting may develop. Insert a naso-gastric tube

at the site of injury to decompress the stomach and prevent aspiration during the evacuation.

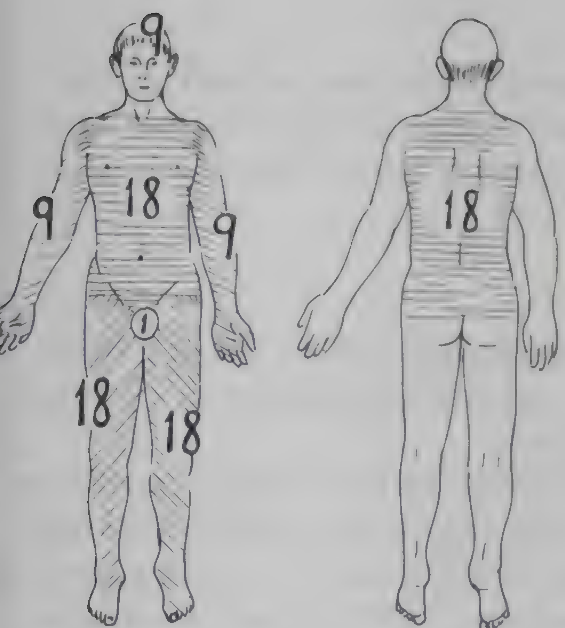
Compartment problems and indication for fasciotomy: p. 177.
The eschar may also restrict the breathing: p. 565.

Compartment problem under the eschar
Eschar is the stiff dead tissue formed on the surface of deep burns. Under the eschar the soft tissues become swollen. If the eschar takes much of the circumference of a limb, a compartment problem develops: The veins collapse; the soft tissue pressure further increases, and may obstruct also the limb arteries. As burn cases are already hypovolemic, the compartment problem in burns develops at a lower tissue pressure: There is a special risk of compartment syndrome compared to non-burn cases.

Examination and classification of burns

TBSA – total body surface area

- **Know the burn area in % of the TBSA** – to make triage, to plan the fluid therapy, to plan the nutrition.
- **Know the burn depth** to plan the surgery.
- **Check for inhalation injury:** It causes airway obstruction, may affect the breathing, and increases the loss of fluids.



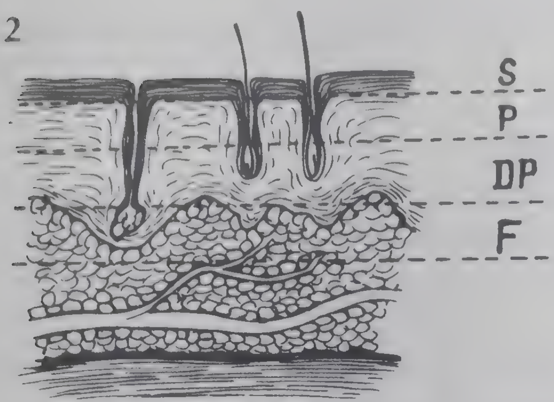
1 Assess the burn area – "The rule of nine" in adults: Each of the body regions constitutes around 9% or 9+9 =18% of the TBSA. For example, a patient with burn wounds covering both upper limbs and the front of his trunk has a burn area of 9+9+18=36% of the TBSA.

The patient's palm is about 1% of the TBSA, and can be used in estimating the injury.

Table 1
Assess the burn area in children – percentage of total body surface

Region	Age 0-1 year	Age 1-4 years	Age 5-9 years	Age 10-14 years	Age 15 years
Head	19	17	13	11	9
Neck	2	2	2	2	2
Anterior trunk	13	13	13	13	13
Dorsal trunk	13	13	13	13	13
Buttock region	5	5	5	5	5
Genitals	1	1	1	1	1
One arm	9.5	9.5	9.5	9.5	9.5
One thigh	5.5	6.5	8	8.5	9
One calf	5	5	5.5	6	6.5
One foot	3.5	3.5	3.5	3.5	3.5

2



The depth of skin burns is often underestimated at first sight. Close monitoring for some days by experienced staff often identifies areas of full thickness injury.

2 **Assess the depth of the burn wound:** Exact early diagnosis of depth is difficult, but an approximate assessment should be done for triage and planning of surgery. The burns are classified as superficial (S), partial thickness (P), deep partial thickness (DP) and full thickness/deep burns (F).

- The superficial burn heals without further therapy. The loss of fluids is minimal.
- A partial thickness burn leaves the deep layer of the skin (dermis) uninjured. Dermis produces the skin cells: A partial thickness burn may heal within 2-6 days. If it is deep (DP) and only some islands of the dermis remain undamaged, it will heal within 2-3 weeks, and leave some scarring in the wound field: Close deep partial thickness burns with skin grafts.
- A full thickness burn (F) does not leave any skin producing elements in the wound. The wound will be covered with a stiff plate of dead skin elements – the eschar. The full thickness wound heals by scar tissue proliferation from the wound edges. The final result will be a massive scar field, painful, with risk of contracture formation (p. 251).

Clinical signs of burn depth

- Partial thickness burn wound:
  - Skin blisters filled with clear fluid.
  - There is some pain sensation in the wound field (prick test with needle).

- Full thickness burn wound:
  - Small thrombosed blood vessels are seen deep in the burn wound (the vessels are located under the dermis).
  - The wound is painless on needle testing (the skin sensory nerve ends just beneath the skin).
  - The skin appears non-elastic.
  - Hairs can easily be pulled out.
  - After some days, the full thickness wound forms a dark and stiff plate of necrotic tissue called eschar. The eschar is a typical sign of the deep burn wound. It may include the subcutaneous tissue down to the muscle fascia, main nerves, vessels and tendons.

Inhalation injury

Early airway complications after the inhalation injury may be due to thermal irritation or burns to the airway mucosa, chemical irritation due to inhalation of irritant or toxic smoke and gases – or both.

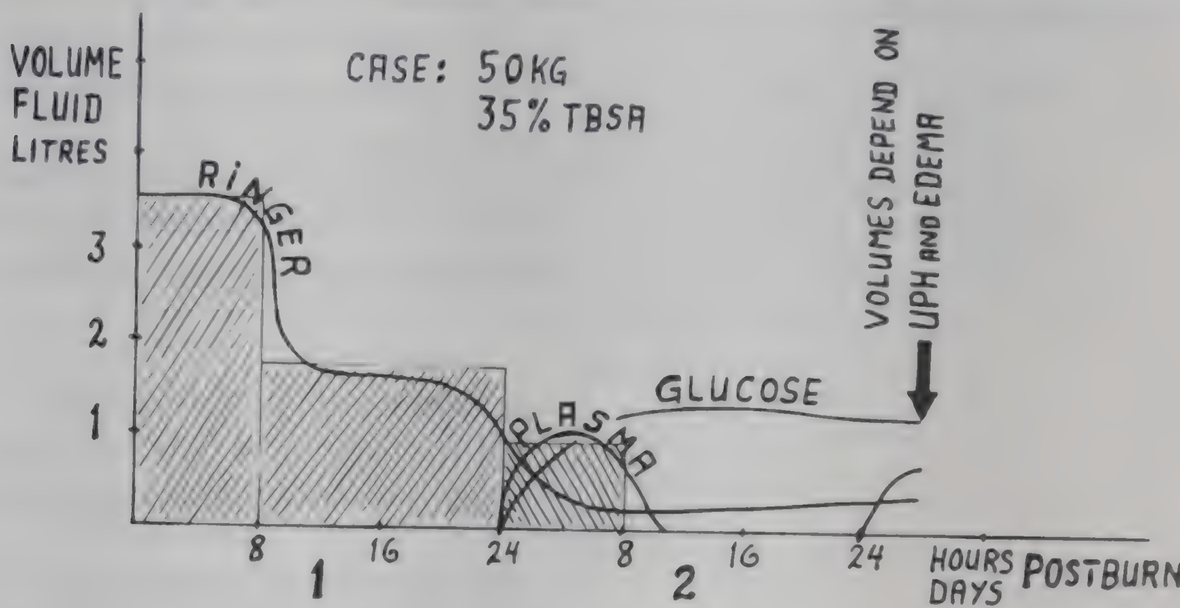
- Signs of chemical damage: Suspect a combined thermal-chemical problem in casualties injured inside a closed space, with inhalation of heavy smoke from burning furniture, oil etc. Carbon monoxide (CO) and/or cyanide poisoning may cause loss of consciousness and death: Give 100% oxygen to comatose cases. Order bed-rest and monitor his condition for 48 hours after injury even if he is without early symptoms.
- Signs of thermal damage: Examine the face and pharynx – burn wounds around the mouth, nose or inside the pharynx indicate airway burn. Wheezing during inspiration indicates upper airway injury. Unrest, high respiratory rate, and wheezing during the expiration indicate damage to the lower airways.

Do not miss the inhalation injury
The early clinical signs may be few: Order bed-rest and monitor risk cases for 48 hours.

Fluid therapy

Assess the early loss of fluids (the Parkland formula):

4ml × kg body weight × burn area in % of the TBSA



The initial fluid therapy – the Parkland regime: Take a burn case, body weight 50 kg, burn area 35% of TBSA. The program for fluid therapy will be

- Fluid needs for the first 24 hours postburn: 4 ml × 50 × 35 = 7000 ml Ringer.
  – Day one, hours 0-8 postburn: Give half the total day volume, 3500 ml Ringer.
  – Day one, hours 9-24: Give the rest of the total day volume, 3500 ml Ringer.

- Fluid needs for day two postburn: The loss of fluids is reduced, but there is still a risk of hypovolemia. Assess the need for plasma or plasma expander by the formula:
  0.5 ml × kg body weight × % area burnt
  Our case needs 0.5 ml × 50 × 35 = 875 ml plasma, blood or plasma expander (dextran, hemaccel). At this point the patient has general edema and a surplus of salt (NaCl): Stop the Ringer, supplement the plasma infusion with glucose 50 mg/ml to maintain the renal function.
  – Plasma expander or blood transfusion on day 2 postburn: 900 ml.
  – Fluid infusion on day 2 postburn: glucose 50 mg/ml to maintain a urinary output per hour of 1 ml per kg body weight – in this case 50 ml urine per hour (UPH).

ue to the much increased vascular ermeability soon after the burn, asma or plasma expanders should ot be used during the first 24 hours ostburn.

Basic life support, volume therapy: p. 148 and 591.

- Fluid needs from day three onwards: Give volume and fluid therapy as outlined for intensive care cases – volumes guided by circulatory signs, the UPH and, if available, serum electrolytes.

Oral fluid therapy
Minor burn cases should be given oral fluid and nutrition. Adults with burns less than 20% TBSA, children with burns less than 10% TBSA: Give sodium bicarbonate and salt in water. Add sugar from the second day postburn. One teaspoon sodium bicarbonate (4 g $NaHCO_3$) is mixed with one teaspoon salt (5 g NaCl) in one liter of water.

Blood transfusion
Several factors affect the hemoglobin level:

Falling hemoglobin level on the first day postburn indicates associated bleeding injury: Identify the bleeding source and control it!

- Hemoconcentration: Normally there is a slight increase in the hemoglobin level on the first day postburn – also when the volume therapy is well run and matches the loss of fluids.
- Patients with full thickness burns of more than 10 % TBSA lose red blood cells and platelets. Also patients with extensive partial thickness burns may develop some anemia. The volume of transfusion needed is indicated by a standard formula:
  % deep burn × 50 = ml blood transfusion
  Give one half of the volume of transfusion on the first day postburn. Additional transfusions may be needed.

Formulas are guidelines only
The loss of fluid and blood elements varies from case to case. Inhalation injury with airway burn increases the need for fluid and volume therapy.

The only safe indicators for the volume therapy
- **Urine production of 1 ml/kg body weight per hour**
- **Hematocrit of 20-25**

Nutrition

The metabolism after burn injuries is increased by 50-100% in relation to the normal condition. In burns of more than 20% of the TBSA, high-energy nutrition is essential to prevent weight loss, reduce the rate of infections, and prevent secondary organ failure.

Basic Energy Expenditure – BEE
It is the energy used by the resting and healthy human body to maintain the vital functions. BEE is given in kilocalories (kcal).

Calculate the need for nutrition

$$
\begin{aligned}
\text{BEE kcal} &= 66 \\
&+ (\text{body weight} \times 13.7) \\
&+ (\text{height} \times 5) \\
&- (\text{age} \times 6.8)
\end{aligned}
$$

The metabolism of a burn case increases with the extent of area burnt. The actual energy need is BEE × 2 or BEE × 3 depending on the extent of the burn, and associated injuries.

eeds for nutrition after injury and
rgery: p. 585.

The feeding procedure

- Start high-energy nutrition 24-48 hours postburn. Moderate cases can take oral and naso-gastric feeding. Major cases where the rehabilitation will be lengthy benefit from gastrostomy tube feeding.
- Start enteral feeding infusion at 50 ml/hour and increase gradually to a maximum of 200-250 ml/hour.
- There is loss of protein in extensive burns, especially if the burn is deep. The feeding diet should contain at least 100 g protein/day for an adult.
- There is some retention of sodium during the first 48 hours postburn. Hypernatremia is increased after high volumes of Ringer infusion. The enteral diet should thus have a low content of salt. No salt should be added to the diet unless serum electrolytes are monitored.

nteral feeding procedures: p. 612.

ake diets of local foodstuffs: p. 616.

Triage of wartime burns

The type of burn affects the triage

- Chemical burns need urgent wound management
- Combined skin burn-inhalation injury increases the early loss of fluid and the risk of organ complications
- Circular deep burn of a limb may cause compartment syndrome
- Extensive deep burns of the chest may obstruct the breathing
- Burns to the groin and buttock area carry increased risk of wound infection
- Deep burns to the face, eyes, hands and feet and deep burns close to joints need special surgery to prevent scar contractures

riage of war casualties: p. 123.

Associated injuries affect the triage

Associated injuries are common in wartime burn cases. Especially in mass casualties, the dramatic burn wounds often attract all attention – and the early diagnosis of associated injuries is missed.

- Take an exact weapon history: Any bomb, heavy artillery shell or cluster weapon may contain burning chemicals. Airplane fire bombs and close-range blast injury from shelling may cause combined thermal burn-shrapnel injury. Modern air-to-ground, double-charged and heat-generating rockets (anti-shelter weapons) may cause very deep burns combined with blast and shrapnel injury.

- Circulatory shock: Even moderate blood loss in any type of associated injury may cause circulatory shock within a few hours due to the burn hypovolemia. Thus a burn more than 20% of the TBSA also increases the priority of the associated injury – be it an abdominal injury or a fracture.
- Respiratory problems: Blast pressure injury to the lungs may complicate the inhalation injury. Both types of injury may be free of symptoms during the first 24-48 hours after the injury.
- Wound infection: Burn wounds with shrapnel and dirt after close-range explosions are contaminated and infected from the time of injury.

The time factor affects the triage

The evacuation of patients may be delayed due to entrapment or heavy military pressure. Cases with burns more than 30% TBSA have high risk of secondary organ failure if the volume therapy is delayed more than eight hours postburn.

The capacity of the medical network affects the triage

- Consumption of materials: A 30% TBSA burn may need 60-80 liters of fluid and 5-10 liters of blood/plasma expander during 10 days.
- Consumption of time and staff: A 30% TBSA burn may need dressing one or twice a day (60 minutes for one or two paramedics) for 2-3 weeks. And 5-10 surgical operations under anesthesia.
- A high risk of complications in burns of more than 30-40% TBSA further adds to the load.

Triage of burn mass casualties

Priority 1: cannot wait – need forward volume therapy and rapid evacuation for basic life support

- All burns of more than 20% of the TBSA in adults
- All burns of 10 % or more of the TBSA combined with other serious injuries
- All burns of more than 10% of the TBSA in children
- Patients with inhalation injury

Priority 2: can wait – need early surgery and special wound care

- All burns contaminated with soil, dirt or shrapnel
- Infected burns late for surgery
- Full thickness burns of 10% or more of the TBSA
- Full thickness burns of the face, hands, feet, and areas close to joints

Priority 3: cases for outpatient treatment and oral fluid therapy

- Quite superficial burns
- Partial thickness burns of less than 20% of the TBSA in adults, less than 10% in children

Priority 4: fatal cases
The definition of Priority 4 cases cannot be exact: Patients with partial thickness and deep burns including 80% or more of the TBSA seldom survive – even when managed in specialized burn centers. Under wartime field conditions the upper limit of what you may probably save is burns around 40-50% of TBSA – much depending on staff skill, resources and the total casualty load. The only treatment for Priority 4 cases should be analgesics and oral fluid.

Basic life support

asic life support procedures: p. 130.

Stick to the priorities common in all emergency medical care.

- A – free airways: Beware the inhalation burn injuries. Do not miss other injuries that cause airway obstruction.
- B – support the breathing: The inhalation injury may cause lung edema and lobar atelectasis. Burn injuries are painful and cause anxiety: Analgesia is essential.
- C – circulatory support: The objective is not to restore the circulation, but to maintain good tissue perfusion and prevent the circulation from collapsing. In major cases aggressive volume therapy should start immediately postburn – in the field.

Forward field management

gns of inhalation injury: p. 558.

he choice of antibiotics: p. 652.

- **Take the weapon history: risk of associated injuries?**
- **Inhalation injury**
  - Intermittent tracheal suction
  - Supine position, head end elevated all the way during the evacuation
  - Treat bronchospasm (i.v. aminophylline)
  - Start broad-spectrum antibiotics
  - Serious cases: Consider endotracheal intubation (awake intubation, p. 138)
- **Breathing**
  - Analgesia: intermittent small doses of i.v. morphine. In hypovolemic cases ketamine analgesia may also help increase the blood pressure
  - Give 100% oxygen to comatose patients
  - Consider sedation, intubation and assisted ventilation in cases with heavy respiratory work and high respiratory rate
  - Insert naso-gastric tube to decompress the stomach and prevent aspiration
- **Circulation**
  - Make a rough assessment of the % area burnt and the body weight. **Notice:** In chemical and high-voltage electrical burns the extent of the deep wound is bigger than what the surface wound indicates.
  - Start Ringer infusion in the field: Volume Ringer (ml) needed for the first eight hours postburn = 4 × body weight × % burn area.
  - Add volume for inhalation injury and associated injuries.

– In major cases and cases where the volume therapy is delayed: two large-caliber i.v. lines. Consider venous cut-down. Do not hesitate to cannulate or make cut-down in burn areas if there is no access through healthy skin.
– Documentation: Write in the Injury Chart (or directly on the patient) the exact time of injury and the volume of fluids before and during the evacuation. Number each bag of fluid, and number correspondingly on the Injury Chart.
– If the evacuation will last more than four hours: Insert bladder catheter. Tell those assisting in the evacuation to step up the rate of infusions if the urine production decreases.
– Prevent hypothermia: Cover the patient and the wounds with blankets even in a hot climate (temperature less than 40 degr.C). Warm the infusions. Consider central warming in extensive injuries.

Complications due to hypothermia after injury: p. 276.

Basic life-saving surgery in multi-injury burn patients

Forward basic life-saving surgery: p. 161.

Early surgery

The extreme loss of fluids in major burn cases makes patients vulnerable to associated injuries that bleed, eg. penetrating chest and abdominal injuries, and compound fractures. In multi-injury cases, effective circulatory support requires early surgical control of bleeding. As most fluids are lost during the first 12 hours postburn, the associated bleeding injury should be managed within 1-2 hours after injury.

One-hour surgery

Surgery done on hypovolemic and hypothermic burn cases carries high risk of circulatory collapse and coagulation failure. Laparotomy and fracture surgery add to the temperature loss. The operation time should therefore be a short as possible: The objective of early life-saving surgery is not definitive repair, but exclusively to manage the main problem at that time. The definitive repair is done when/if the patient is stable 24-48 hours postburn.

Examples of one-hour basic life-saving surgery in burn cases

- Associated abdominal injury: Tie the intestine to prevent fecal leak; gauze pack the abdomen to control bleeding.
- Associated vascular limb injury: As artery reconstructions are time consuming, tie the vessel.
- Limb crush injury, double fractures: There will be an extensive soft tissue injury that adds to the fluid loss and increases the risk of septicemia and secondary organ failure – consider primary amputation.
- Open fractures: Definitive debridement and fracture fixation are time consuming – do fasciotomy and double drainage and arrange for traction. Delay the debridement for 24-48 hours.

lanage airway obstruction: p. 136.

Clinic management

- **Airways**
  - Signs of inhalation injury: Order bed-rest, monitor airways and respiration for 48 hours even in cases without respiratory distress
  - Airway obstruction: Analgesia and sedation. Repeated tracheal suction. Aminophylline for bronchospasm. Consider intubation and assisted ventilation. Consider tracheostomy
- **Breathing**
  - Analgesia is essential for effective breathing
  - Wide deep burns of the chest and abdomen: Escharotomy incisions improve the respiration (ill. 3)
  - Inhalation injury: Oxygen. Broad-spectrum antibiotics
  - There is risk of paralytic ileus: frequent suction on naso-gastric tube
- **Circulation**
  - Examine the forward therapy and assess the fluid balance so far: Compensate for fluid deficit immediately
  - Circulatory shock on admission: Control bleeding from associated injuries. Start immediately blood transfusion or plasma expander until urinary output per hour is 1 ml/kg body weight, and hematocrit is 25
  - Circumferential deep burn on a limb: Do escharotomy to prevent compartment syndrome (p. 521 and 557)
  - Plan the fluid therapy – fill in the Burn Case Chart: Estimate requirements and monitor the fluid balance, the urinary output, the general edema (weight gain and loss), and the hematocrit
- **Nutrition**
  - Estimate the actual energy requirement in kcal (p. 602).
  - Start nutrition on day 2 postburn: Make a glucose-protein solution of local foodstuffs. Give 50 ml/hour peroral or by naso-gastric tube, increase gradually to 200 ml/hour.
  - Burns 30% TBSA or more: Consider arranging for gastrostomy or jejunostomy tube feeding when the patient is circulatory stable (day 2 or 3 postburn).
  - High-energy nutrition: Protein-glucose solutions cannot match the need of calories – make diets rich in protein and fat from local foodstuffs.

ontrol external bleeding: p. 144.
ontrol internal bleeding: p. 144.

lome-made diets for enteral feeding:
. 622.

3

3 Emergency escharotomy: When edema builds up under the stiff escharplate, the eschar of a deep circumferential limb burn may cause a compartment problem. Wide eschar fields on the chest and abdomen may restrict the breathing. Escharotomy may be done bed-side without anesthesia as the eschar itself is insensible. One or more longitudinal incisions are made through the eschar into bleeding subcutaneous tissue. The soft tissue pressure will widen the incisions and confirm that escharotomy was necessary.

Burn Case Chart Salween **Clinic**

Patients name: Ne Win Sex: (M) F Weight: 70 kg

Address: Mae Sot Age: 50 Height: 180 cm

Father's name:

Type of injury/weapon: Antishelter rocket (flash burn + inhal + shrapnel) Time of injury: February 10 6 a.m.

Total area burnt: 40 % TBSA Area full thickness burn: 10 % TBSA

Thermal inhalation injury: (Yes) No Chemical inhalation injury: Yes (No)

Associated injuries: Penetrating chest wound, hemothorax R
Open femur fract. L

Standard requirements

ml Ringer day 1 postburn = 4 × kg × % area burned
ml plasma day 2 postburn = 0,5 × kg × % area burned
ml blood day 2 postburn = 50 × % area deep burn

Add for: bleeding injury, abdominal injury, fever more than 38 degr.C
Optimal urinary output per hour = 1 ml × kg

		Day 1		Day 2		Day 3	
		1-8 hrs	9-24 hrs	1-12 hrs	13-24 hrs	1-12 hrs	13-24 hrs
Requirements	Fluids	6500 +2000	6500	6500	6000	6000	8000
	Plasma			750	750	750	750
	Blood	1000		500			1000
	Nutrition						(surgery)
Actual input	Oral			300	200	N.P.O.	—
	I. v. fluids	3000 Ring	7000 Ring 2000 Ring	5000 Gluc 2000 Ring	4000 Gluc 2000 Ring	4000 Gluc 2000 Ring	4000 Gluc 4000 Ring
	Plasma						
	Blood		1000	1000	1000		1000
Urine	Total	?	670	1000	900	720	740
	Mean per hour		0,8ml/Kg	1.2ml/ky	1,1ml/kg	0,8ml	0,8ml/kg
	Body weight (general edema)		70	69	72	74	76

	Day 1	Day 2	Day 3
Dressing		✓ Ketam. ✓ Ketam	✓ Ketamin
Surgery	Debrid. Chest tube Tibialtraction		External fixation femur L Debrid. burn
Comments	iv Ketamine Analg: morphine i.v Dressing: ketamine i.v.		

Case study: a multi-injury patient

Your patient is 50 years old, his weight is 70 kg and his height 180 cm. His shelter was hit by a heat-generating rocket, and he has combined injuries: flash burns of 40% of the TBSA, respiratory wheezing indicating airway burn, shrapnel injury to the chest with signs of hemothorax, compound open fracture of one femur with a fracture hematoma estimated to be 1000 ml. He arrives at your clinic 12 hours after the injury. He got 3000 ml Ringer during the evacuation and arrives in grave circulatory shock.

- **The basic life support**
  - Airways: Tracheal suction. Postural drainage: alternate supine position – left-side position – right-side position.
  - Breathing: half-sitting position. Ketamine analgesia (repeated i.v. doses of 40 mg). Oxygen. Chest tube: 500 ml blood is drained immediately. Naso-gastric tube.
  - Volume therapy:

    (1) Requirement due to the burn: 4 × 70 × 40 = 11 200 ml the first 24 hours, of which approximately 7000 ml should be given during the first 12 hours. There is thus a deficit of 7000 – 3000 = 4000 ml Ringer on admission.

    (2) The fluid requirement is increased in cases with inhalation injury: Add 1000-2000 ml Ringer.

    (3) Requirement due to 1500 ml blood loss: 2500 ml Ringer compensates 1 liter blood loss. This patient needs approximately 4000 ml Ringer to compensate the blood loss. Better give 1000 ml blood transfusion or plasma expander, and add 1000-2000 ml Ringer. The initial fluid therapy is thus flush infusion of 4000 + 3000 = 7000 ml Ringer and 1000 ml blood/plasma expander by double large-caliber i.v. lines (venous cut-down). Further volume therapy depends on the urine production and chest blood loss.
  - Delay surgery: The risk of airway complications and circulatory collapse is high. Drain the femur fracture and arrange for traction, but delay debridement and fracture fixation until the patient is in stable circulatory state and nutrition is established (day 3 or 4 postburn).

Note that some hemoconcentration (increasing hemoglobin value) is common on the first day postburn in major burn cases. The hemoconcentration may hide blood loss due to associated injuries.

- **Fluid therapy 12-24 hours postburn:** The rest of the first day's total volume makes 11 200–7000 = 4200 ml Ringer. Add for increased loss due to the inhalation injury. Add for chest blood loss.
- **Day 2 postburn**
  - Fluid therapy: Give 0.5 × 70 × 40 = 1400 ml plasma or plasma substitutes to prevent hypovolemia. As this case has some blood loss due to other injuries, 1000 ml should be given as blood and 500 ml as dextran. Start infusion glucose 50 mg/ml with infusion rate necessary to maintain a urinary output per hour of 1ml per kg body weight, that is 70 ml urine per hour. The volumes of glucose needed will probably be around 2 × 70 × 40 = 5600 ml, some of it given by enteral feeding tube (see below).
  - Start nutrition: His basic nutritional needs are

    66 + (70 × 13.7)
    + (180 × 5)
    – (50 × 6.8)
    = 1585, that is 1600 kcal/day. Consider him a stress level-3 case due to multiple injuries and extensive burns: That makes the actual energy need 1600 × 2 = 3200 kcal/24 hours. This patient carries high risk of complications, the rehabilitation will take time – enteral feeding should be arranged:

Assess the stress level: p. 603.

Make gastrostomy with large-caliber feeding tube under ketamine anesthesia. Start feeding with a glucose-protein solution at a rate of 50 ml/hour, increasing gradually to 100-200 ml/hour.

- **From day 3 postburn**
  - Volume therapy to maintain urinary output around 70 ml per hour: 1000-1500 ml per day of blood/plasma/plasma expander.
  - Enteral fluid therapy and nutrition: Give a high-energy diet made of local foodstuffs, 200-300 ml per hour.
  - I.v. fluid therapy: The patient can take a maximum of 5000-6000 ml by the enteral tube. Add 2000-4000 ml of Ringer and/or glucose 50 mg/ml i.v.

Management of the burn wound

The objective: to close the wounds as soon as possible to reduce the loss of fluid, and prevent wound infection.

Management at the site of injury

- Cool the burn wound immediately: Cooling in water may reduce the heat damage to the tissues. Cool until the pain is relieved (20-40 minutes). If applied more than 15 minutes after the injury, cooling may be less effective in reducing the depth of the burn, but the analgesic effect is still good.
- Cover the wound: Any clean cloth available may be used as dressing. Let the dressing be well padded and thick to absorb wound discharge.
- Prolonged and difficult evacuations: Apply splints or padded plaster casts for protection and pain relief.
- Cover the patient with blankets: Hypothermia (32-34 degr.C) may develop in extensive burn cases. Clinical signs are drowsiness, confusion and shivers.

No prophylactic antibiotics!
The burn wound infections are best prevented by proper debridement, topical antimicrobial creams, early skin grafting and early high-energy nutrition. Broad-spectrum antibiotics are reserved for inhalation injuries, and secondary infections when a specific bacterial diagnosis is established.

Debridement of the burn wound

As with any other wartime wound, the burn wound is debrided as soon as possible after injury – but not until the patient is in a stable circulatory state. Before taking the patient to the operating room, burnt clothes and dirt are removed and the wound fields washed with soap solution. Clothes and dirt burnt into the tissues are removed by the surgeon with the patient under anesthesia. If surgery is delayed, dressing with dilute soap solution is applied directly on the wounds until surgery is done.

Clinical signs of burn depth: p. 558.

The debridement is diagnostic

Debride necrotic tissue not attached to the dermis. Leave blisters intact as they act as protective dressings. Remove all particles of cloth and dirt by careful brushing or sharp dissection. Examine closely and classify which of the burns are superficial, partial thickness or full thickness burns.

The further wound management differs depending upon the extent and depth of the injury, and the skills and capacity of the medical staff.

Wound care strategies

- Either closed wound care with antimicrobial burn cream
- Or exposure wound care

  We recommend closed wound management under field conditions: It involves less staff care, and carries less risk of infections.

Strategies for surgery

- Superficial burns heal spontaneously.
- Deep partial thickness burns: early or delayed skin grafting.
- Full thickness burns: early escharectomy and skin grafting, or spontaneous separation of the eschar and delayed grafting.

  In general we recommend early skin grafting and early escharectomy: It reduces the loss of fluids, reduces the risk of wound infections, makes rehabilitation shorter, and reduces the overall load on the clinic.

Eschar: the rigid dead tissue in a full thickness burn wound.
Escharotomy: longitudinal splitting of the eschar.
Escharectomy: excision of the eschar.

A tight vaseline gauze causes fluid retention and wound infection: Pull some threads from the gauze.

Closed wound care

Topical antimicrobial burn cream is applied to the wound, and the wound covered by wide-mesh vaseline gauze. A thick absorbing dressing of sterile gauze is applied outside the vaseline sheet. Splinting is done during the first three days in extensive burns of the limbs, then active joint exercises are encouraged. The dressing is removed every 1-3 days for wound monitoring, soap washing and repeated bed-side debridements. Closed wound management is the method of choice in out-patient cases, under dirty field conditions and during evacuation. For prolonged evacuations and out-patient treatment of limb burns, the Trueta plaster method may be used: The plaster protects the wound during transport; it reduces the pain and effects continuous good wound drainage. The Trueta plaster is also the method of choice in limb burns combined with extensive soft tissue injuries or fractures.

The Trueta plaster method: p. 182.

Exposure wound care

The method requires hygienic conditions. After cleaning the whole patient with/in soap solution, apply topical burn cream and leave the wound fields exposed to air. Wash and debride the wounds every 1-3 days. Minor and superficial burns may be left exposed to dry air without burn cream application.

Burn creams
The use of special burn creams will reduce the risk of burn wound infection. There are several antimicrobial agents available – they all have some advantages and disadvantages. The two most common ones are
- Silver sulfadiazine burn cream has a wide antibacterial action. It does not penetrate into deep burns, and is good for exposure management of superficial partial thickness burns. The application is painless.
- Sulfamylon burn cream (mafenamide acetate) has a potent antibacterial action even on pseudomonas. The drug penetrates even deep burns. The application of Sulfamylon is painful in partial thickness burns. The cream causes hypersensitivity reactions in one out of ten cases.

You may combine or alternate the two agents, using Sulfamylon on the areas of deep burn and silver sulfadiazine for the partial thickness burns. Or silver sulfadiazine may be applied to deep burns after partial excision of the eschar down to a thickness of 1-2 mm: The drug will then penetrate the eschar and help prevent infection under it.

Deep partial thickness burns: early skin grafting
Thin split-thickness skin grafts reduce the evaporation and exudation through the burn wound. Also skin grafts are the best possible"dressing", and help prevent wound infection. Start grafting as soon as the patient is in stable circulatory state. The main problem in extensive burns is lack of donor areas: Better take very thin grafts to be able to reuse the donor areas every 2-3 weeks. Meshing enlarges the grafts and improves drainage through the grafts. Use meshing machine or cut numerous small incisions in each graft.

Skin grafts – the technical procedure: p. 252.

Full thickness burns: early escharectomy and skin grafting
Fluid collecting under the eschar of full thickness burns makes a base for local infection. Excise eschar as soon as the patient is in a stable state. Escharectomy to the fascia is the safest procedure.
- Alternative 1 – escharectomy to the fascia: The eschar is excised together with the subcutaneous tissues down to the muscle fascia. The excision is done by blunt and sharp dissection along the fascia. Bleeding vessels are carefully clamped and tied, the blood loss is moderate. Then apply split-skin grafts on the fascia; the take is normally good.
- Alternative 2 – tangential escharectomy: The eschar is excised layer-by-layer until you reach healthy tissue. One-step complete tangential escharectomy bleeds much and must be done in a bloodless field – which makes it difficult to assess tissue viability as you cannot see the bleeding from capillary vessels. Better do two-step escharectomy: First do a partial excision, then apply burn cream (mafenamide acetate), and await the demarcation of the eschar (1-2 weeks) before the definitive escharectomy is done.

Bloodless field: p. 680.

Some particular problems in burn wound care

Primary amputation may be life saving

Patients with extensive full thickness burns carry high risk of septicemia and secondary organ failure. If they also have major associated injury, the risk is much increased. Primary amputation of a fractured or crushed limb may be life saving.

Lack of graft donor areas: Use human allografts

HIV and hepatitis B virus have been transmitted by allografts.

Lack of suitable skin donor areas is a problem in extensive burns. Synthetic and biologic skin substitutes are available, but very expensive. Human allografts may solve the problem: Harvest split-skin grafts from relatives or friends of the patient, or from volunteers. Collect many grafts and store them under sterile conditions in refrigerator. The allografts will primarily stick to the patient's burn wound as his own skin grafts. But within 1-2 weeks they will become detached and should be removed at the dressings. In the meantime they serve as a valuable biological wound dressing for many days, restricting fluid loss and preventing local infection.

Deep burns to the hand and foot

To prevent scar contractures, the eschar must be removed. There are two strategies:

- We recommend conservative mangement: Wash the wound three times a day, apply silver sulfadiazine, and cover the whole hand or foot in plastic bags or gloves. Within 2-4 weeks the eschar will separate spontaneously, and can be removed stepwise at the dressings. Intensive active and passive exercises under analgesia, and splinting during the night help prevent contractures. Grafting is done when the eschar is removed – with free grafts or full thickness flaps.
- Primary surgical escharectomy may also be done. But in deep wounds it may cause damage to vessels, nerves and tendons. Cover the wound with full thickness grafts or flaps after escharectomy.

Burns to the face

Tarsorrhaphy: p. 335.

Partial thickness face burns heal rapidly without surgery. Full thickness burns close to the eyes and mouth are managed by primary excision and full thickness skin grafting/flaps to prevent contractures. Use tarsorrhaphy sutures to prevent contractures of the eyelids.

Burns to the cartilage

Deep burns of the nose and ears may cause necrosis of the local cartilage with chronic suppuration. Excise the necrotic cartilage at an early stage to prevent infection. Reconstructive surgery is done later.

Thermal bone necrosis

The heat exposure from modern heat-generating missiles is intensive. Also the subcutaneous tissue and muscles may be damaged. Where the bone has poor soft tissue padding (hands, feet) the heat exposure may cause extensive vascular damage and thrombosis: Within some days postburn, the bones become soft, waxy and start to suppurate. Osteomyelitis will develop unless all dead bone is

excised, and the wound covered by healthy soft tissue (local or distant muscle-skin flaps).

Diversion colostomy: p. 378.

Burns to the perineum
There is risk of secondary infection from urine and stools. Use exposure wound management. Insert bladder catheter. Consider temporary diversion sigmoidostomy in extensive perineal wounds.

High-voltage electrical burns

High voltage: more than 1000 volts (V).

Burns due to electricity are common in city warfare, persons trapped in bombed buildings are specially at risk.

The electrical burn differs from the thermal burn
The superficial skin wound may be small, but the internal damage is extensive: The electricity follows the deep structures, and may cause vascular injury with thrombosis, and necrosis of muscles, nerves and tendons far away from the inlet wound. Release of myoglobin from extensive muscular injury may cause renal failure.

The management
- Monitor the heart: The early mortality is high due to cardiac arrhythmia or arrest. Close cardiac monitoring is done for 2-3 days after injury.
- Fasciotomy: Extensive internal injury and small inlet wounds make a high risk of compartment syndrome. Early fasciotomy may be limb saving.
- Surgical exploration should always be done: The internal injury is normally more extensive than expected.
- Debridement: You may make a rough primary debridement. We recommend delaying the definitive debridement for 2-3 days for better demarcation of the muscle necrosis.
- Extensive muscle necrosis – prevent renal failure by giving large amounts of fluid to maintain an urinary output of 2 ml/kg body weight per hour. Give alkaline buffer infusion (sodium bicarbonate 500 mmol/l) to get alkaline urine. Consider primary amputation.

Muscle crush injury and renal failure: p. 592.

Chemical burns

Particles or droplets of phosphorus or napalm cause circular deep skin burns. If the chemical is not removed immediately, it gradually penetrates deep into the tissues until all the active agents are burned out. Shrapnel from grenades and cluster weapons may also contain burning agents and cause extensive internal injury.

The essential management of chemical wounds is done at the site of injury: The burning chemical must be removed as soon as possible. Use any knife at hand to cleanse/excise the wounds.

n other types of chemical burns eg. y acids or caustic soda: Wash imme- liately with water.

Do not pour water in the wound: Phosphorus starts boiling and spreads inside the wound field making debridement more difficult. In theory, topical copper sulfate solution and potassium permanaganate solution will neutralize phosphorus and napalm inside chemical burns. In real life the neutralizing solutions are not very useful: They are not available in the fighting area; on clinic admission the active agent normally would have burned out. We recommend that all paramedics, village health workers and fighters be instructed to do surgical cleansing of the chemical war wound.

Complications of burns

Burn wound infection

Let experienced staff dress and monitor extensive and deep burn wounds to diagnose wound infections as early as possible. The signs of infection:

- Increased wound discharge, foul smelling or change in color of the discharge.
- Healthy granulations turn pale and degenerate.
- Separation or "poor take" of thin split-skin grafts (normally due to beta-hemolytic streptococci).
- Secondary spontaneous bleeding from the wound.
- Cellulitis or formation of small abscesses in healthy skin around the burn wound.

The management:

- Explore other sources of infection: a missed injury from penetrating shrapnel, thermal necrosis of cartilage or bone, and infection in a long-term i.v. catheter.
- Burn wound infections are primarily managed by frequent (three times a day) soap or saline baths with debridement and application of burn cream.
- Consider systemic antibiotics: Early infections (first week postburn) are mainly caused by gram-positive bacteria, and respond to penicillin. After 1-2 weeks gram-negative bacteria dominate (E.coli, pseudomonas): Tobramycin and cephalosporins may be effective. **Notice:** The bacterial diagnosis of burn wound samples is uncertain as the bacterial population is usually mixed.

Infection in deep burn wounds

Discharge and bleeding from under the eschar, and early separation of the eschar are signs of deep burn wound infections. Note that anaerobic infections may develop under the eschar. The management consists of the following:

- Escharectomy: Remove all eschar by excision down to the muscle fascia.
- If for some reason complete escharectomy is not possible, inject broad-spectrum antibiotics fanwise under the eschar plate twice daily.
- Give metronidazole i.v. to prevent anaerobic infections.

Management of gas gangrene: p. 580.

Acute renal failure in extensive burn cases

The main cause of renal failure in burns is hypovolemia – the patient has fluid deficit. To prevent permanent renal failure, early diagnosis of low urinary output and immediate volume therapy is essential:

- Monitor the overall fluid balance and calculate the urinary output per hour for every 8-12 hours
- If the urinary output becomes low, flush a bolus of i.v. fluid
- If the urinary output does not increase, give mannitol or diuretics

The management in detail: p. 591.

Gastritis and gastric bleeding

Gastro-duodenitis secondary to major burns may be fatal due to massive spontaneous bleeding from the stomach. The risk is reduced if oral or enteral feeding is used. Major burn cases should have prophylactic antacid every four hours.

Respiratory and multiple organ failure

These serious complications are common in extensive burns, and may develop as late as 1-2 months postburn. Monitoring and management: Chapter 41.

Section 5

Treatment after surgery

Points to note – Chapter 41

Learn to monitor and manage the war wound after surgery: Study the complete section carefully

Learn to monitor and support the vital functions after surgery: Study the complete section

Know the clinical signs of
- respiratory failure: p. 588
- circulatory failure: p. 590
- renal failure: p. 591
- coagulation system failure: p. 593

Know how you can reduce the risk of multi-organ failure: p. 596

41 Monitoring and complications after surgery

Monitor the war wound

The daily dressings are diagnostic
To reduce the risk of septicemia and secondary organ failure, early diagnosis of wound necrosis, infection and abscesses is essential. That diagnosis can only be done by experienced staff monitoring all major war wounds at daily dressings.

Train your staff in wound care
The open debrided war wounds are like "windows" through which the physiology of repair can be studied at close range. Take the time needed to train your staff in essential clinical signs: to identify necrotic tissue, to distinguish healthy granulations from deteriorating granulations, to use the color and smell of the wound discharge as indicators of secondary infection, to explore causes of delayed healing. Join them during daily dressings of major war wounds for training.

Quality control: Register the rate of redebridements. Frequent re-debridements indicate poor quality primary surgery. Monitor the results of each surgeon. Also see p. 697.

Increase the clinic capacity: Organize wound care routines
The post-operative management of war wound makes a heavy demand on the clinics. The matter of organization is a matter of clinic capacity – and should be a concern for the senior surgeon:
- Implement strict routines to make the daily dressings less time consuming.
- Expert wound monitoring and an aggressive approach to re-debridements reduce the rate of secondary complications, and reduce the rehabilitation time – and increase the turnover of patients.

The wound care

The disinfection

Warning: There are lots of chemical disinfectants. Most of them are expensive, some of them cause toxic or allergic reactions in the wound field. Medical staff tend to rely upon the claimed bactericidal effects of "super-solutions": As no disinfectant takes effect within seconds, the result is hurried – and poor – disinfection.

Disinfection and sterilization: p. 656.

Disinfection – the terminal death time of bacteria: p. 658.

Recommendation: For several reasons we recommend solutions of plain soap (without additives) in boiled water as the standard disinfectant:
- The disinfectant capacity of soap is as good as most chemical agents – provided you use the time needed for disinfection.
- Plain soap is always and everywhere available at low cost and in sufficient amounts.
- Standard soap solutions of varying concentration may be used as the general disinfectant: washing of hands before surgery, washing operating fields before surgery, personal hygiene, wound toilet, instillation into joints and deep wounds, and washing of beds and clothes.
- There are few toxic and allergic side effects of plain soap solutions.

Bacteria grow in dilute soap solutions in hot climate: p. 657.

Topical antibiotics and concentrated chemical solutions have no place in wartime wound management.

NaCl solutions

NaCl-wet gauze for dressing has a particular effect in speeding up the growth of wound granulations. Dressing with meshed gauze wet with NaCl 0.9% is used directly upon the raw wound surface; change the dressing 3-4 times a day. Slightly concentrated NaCl solutions will further stimulate the wound granulations, and may be used the last 2-3 days before skin grafting.

Hydrogen peroxide solution

Small amounts of the 2.5% or 4% solution are used to clean a wound where there is much debris, dirt and blood clots. Let the solution act for half a minute. The peroxide solution may also be used where gauze drains are stuck deep inside the wounds.

The problem of pain during dressing

Painful dressings should generally be avoided:

- Pain interferes with the physiology of repair and delays the recovery.
- Pain and unrest during dressings make the dressing hurried – thus the wound exploration and bed-side debridement suffer.
- Pain is not necessary – you have the means at hand to prevent it: I.v. morphine 5 mg with diazepam 5 mg is an effective standard painkiller. For major dressings and exploration of deep wounds, low-dose i.v. ketamine is routine.

ases with risk of drug addiction: se ketamine or nerve block esthesia.

The standard dressing procedure

Identify the main risk for each major wound

The surgeon doing the primary debridement should always note in the Patient Chart what is considered the main problem in each major wound. The paramedics doing the dressing should specially monitor that problem.

e the example on p. 53; the sur-
eon notes risk of rebleeding from
e right thigh wound.

At surgery: Apply bulky dressings

The post-operative management may be rough (evacuation, field conditions). Most wartime clinics have carriers of multi-resistant gram-negative bacteria among their patients: Bulky dressings reduce the risk of secondary wound infections.

Do the first dressing five days after the debridement

To remove the dressing early increases the risk of secondary wound infection. Five days after surgery you may identify wound infection and necrosis.

- Examine the old bandage: Study the debris and exudate on the inner layer of gauze, its color and smell. Has it changed from the days before?
- Examine the wound: Retract the wound edges carefully, explore the deep wound pockets with a finger. Does the wound smell?
- Soap bath: 15 minutes in 5% soap-water solution is a standard for limb wounds. After the bath the wound is rinsed with abundant boiled water or NaCl solution. Or soap solution is instilled in deep wounds for 15 minutes.
- Bed-side exploration and debridement: Again retract the wound edges. Smell, inspect and explore the tissues systematically – the skin, subcutaneous fat, muscles, bone. Minor necrosis is debrided bed-side with sharp surgical scissors and knife. Major necrosis or "possibility of abscess" formation is a definite indication for surgical redebridement on the operating table that same day.
- Drain the wound: Dry fluffy gauze has excellent draining capacity. The more exudate there is, the more frequent the dressings. Introduce the gauze carefully into every deep wound pocket. Do not press the gauze tightly into the wound: That causes tamponade and fluid retention.
- Suction dressing: Where you expect much discharge, make a dressing with several layers of cotton between layers of meshed gauze.

Slight compression improves the drainage: Use circular crepe bandage. Longitudinal adhesive tape outside the crepe bandage will prevent folding of the bandage that obstructs the venous drainage.

Monitor the wounds for particular infections

- **Gas gangrene and other clostridial infections:** The first signs are general – unrest, excessive pain, high pulse rate, some fever. The local signs come late – discoloration of skin, discharge with sweet smell. Local crepitation of gas in the tissues is a very late sign. The management consists of intensive volume therapy and cardiac support, see septic shock management, p. 645; penicillin (20-40 mega IU/24 hours) **and** metronidazole **and** lincomycin; several wide fasciotomies with careful excision of all infected tissue as early as possible; amputation is done if the infection does not respond to these measures. **Notice:** Hemolysis is common in gas gangrene, blood transfusion may be necessary.

The bacteriology: p. 648.

- **Necrotizing fasciitis:** The early signs are of the general type – sudden onset of high pulse rate, fever and septic shock. Local signs are cellulitis with reddish skin, stone-hard subcutaneous edema with underlying necrosis of the fascia. The management is wide surgical excision of the necrosis and high-dose antibiotics.

The bacteriology: p. 646.

Reasons for delayed wound healing – check list

- Soft tissue infection: Explore the wound under anesthesia. Explore especially the deep pockets and tissues close to compound fractures. Study the anatomy: Search for abscesses in all spaces where fluid may collect.
- Necrotic bone fragments: X-ray films may identify major necrotic detached bone fragments. Minor free fragments are seldom seen on the films; still they may cause chronic low-grade suppuration: Explore the fracture under anesthesia.
- Poor tissue oxygenation: Test the proximal pulse beat and the distal capillary circulation. Rule out intimal injury and artery thrombosis.

Rule out respiratory insufficiency (atelectasis, pneumonia, inactivity). Rule out anemia.
- Poor venous drainage: The wound edges are swollen, the limb may be edematous. A bandage applying pressure to the wound edges may accelerate the healing: Cut a hole in a soft rubber plate corresponding to the wound edges. Place the rubber plate onto the wound and apply compressive bandage outside it. Elevate the limb and mobilize the "muscle pump" by active isometric exercises.
- Low-energy nutrition: Poor nutrition may cause protein breakdown and delayed healing. Weight loss is a good indicator.
- Vitamin and/or mineral deficiency may cause delayed wound healing.
- Mental problems: Depression and anxiety cause inactivity. The general condition worsens, the wound healing is delayed.

Organize the wound care

Organize teams of experienced paramedics

Let the teams do the wound care. Select a head paramedic for the dressing teams: He is responsible for scheduling the daily dressings, consulting the surgeons on complications, selecting and reporting cases that need redebridements. The head paramedic of the bed department is a key officer – a good one is indispensable, and will set a standard for the rest of your staff.

Organize the clinic – prevent hospital infections

acteriology – gram-negative infecons: p. 649-651.

-3 weeks after injury is the time hen most gram-negative infections evelop.

ecentralized patient care: p. 30.

There will be cases with post-operative peritonitis, infected fractures and delayed wound healing in most wartime clinics. These patients are most likely carriers of multi-resistant strains of gram-negative bacteria, and a source of cross-infection to all other patients. The multi-injury patients and burn cases are at risk: Their immune system failure makes them attract secondary gram-negative infections. Thus the pool of gram-negative infected, long-term cases may extend until you have a state of permanent hospital infection which complicates any surgery done in the hospital. As there are many reasons why infections spread, the preventive measures are also many:
- High turnover of patients, early mobilization out of bed, and early transfer to rehabilitation centers reduce the risk of cross-infection.
- Mobile field clinics carry less risk of hospital infections than the in-house stationary clinics. Hospital infections are less likely to develop under sunny, dry conditions. Consider moving the clinic frequently during the rainy season.
- Keep infected cases and chronic cases (one-week limit) in a separate bed department. Reserve a separate operating room for them.
- Having a clean bed, a clean patient and a clean paramedic are preventive measures. Personal hygiene among the medical staff and the patients is not a personal matter: Set a standard and monitor it closely.
- Organize washing routines for patients, beds, clothes, furniture and instruments. The consumption of soap and water will be tremendous: So where there is lack of clean water, decentralize the clinic system.

Stop the irresponsible use of broad-spectrum antibiotics
- Multi-resistant strains of bacteria develop under the pressure of broad-spectrum antibiotics: The risk of hospital infections increases.
- These drugs are too expensive. Cheaper measures have better preventive and curative effect: soap, boiled water and the surgeon's knife.
- Serious side effects: The potent antibiotics destroy the bacterial population of the intestines and may promote multi-organ failure.

Intestinal dysfunction may cause multi-organ failure: p. 596.

Organize the production side
Arrange a production unit and a dry store for dressing materials: Considerable quantities of gauze, bandages, soap solution, clean bedclothes and patients' clothes must be available for mass casualties. Engage ambulant patients, their families and the village population in the production.

Monitor the surgery: quality control programs
As secondary gram-negative infections are an important and common risk factor in wartime surgery, we recommend some sort of quality control regarding the post-operative results. An increasing rate of post-operative wound infections and gram-negative pneumonia should then be noted, and preventive measures intensified. To collect long-term results is difficult as war casualties are often transferred for further treatment, or evacuated for military reasons. But all clinics should be able to collect short-term results for a limited quality control program:
- Register the rate of wound infections 5 and 15 days after the time of injury.
- Register the rate of pneumonia 5 and 15 days after the injury.
- Group the patients according to the severity of injury: critical, severe, or moderate. Also group the patients according to their stay in hospital: more than ten days, less than ten days, out-patients. Compare the rates of early and late infections in different groups of patients: An increasing rate of late infection in moderate cases indicates a hospital infection problem. The more so if the rate of infection also increases for the short-term patient group.

Quality control programs: p. 697.

Monitor vital functions

The war wounds are many, but not all will need expert wound care. The war casualties are many, but not all will need expert monitoring and intensive post-operative care. Select the risky wounds and the risky cases, and concentrate on them:

The five factors of post-operative monitoring
- **The wound risk assessment** identifies what is the main problem in each major wound. Person responsible: the surgeon having done the primary wound debridement.

- **Monitoring the major wounds** by daily dressing. Persons responsible: experienced paramedics.
- **The general risk assessment** identifies which cases carry special risk of septicemia and organ complications. Persons responsible: the surgeon having done the primary surgery.
- **Bed-side monitoring** of clinical signs of organ failure. Persons responsible: experienced paramedics.
- **Laboratory monitoring** – advanced laboratory tests are seldom necessary.

lso see organ failure, special risk ases: p. 98.

Risk assessment – select the high-risk patients for close monitoring:

- All patients that had poor vital signs and intensive basic life support between injury and surgery. Known aspiration to the airways, and lasting circulatory shock are factors that especially increase the risk of organ failure
- Late for surgery: cases infected at the time of primary surgery
- Hypothermia: major wounds and burns, extensive surgery with long operation time, high volumes of cold infusions, lengthy off-road evacuations
- Reoperations
- Multiple blood transfusions (more than ten)
- Poor general condition due to other diseases and/or starvation
- Elderly patients
- Others: Lung contusion and fractures of pelvis and the long bones are special risk factors

Bed-side monitoring

Let one nurse be mainly responsible for the same patient. Thus minor day-to-day changes are noted in due time.

Ianagement of respiratory failure: p. 89.

Monitor the respiration

- Respiratory work: Is the respiration labored, the patient exhausted? The reason may be respiratory failure with increasing stiffness of his lungs. Fatigue is a poor prognostic sign.
  Measures:
  – Elevate the head end, half-sitting position
  – Oxygen
  – Consider gastric decompression: naso-gastric tube suction
- Respiratory rate: Frequency higher than 35/minute and thoracic (shallow and dog-like) respiration? The reason may be anxiety, pain, abdominal complications, or respiratory failure.
  Measures:
  – Oxygen
  – Rule out abdominal abscess formation
  – Intensify analgesia, consider intercostal nerve block or pleural anesthesia through the chest tube

- Airway obstruction: Excessive mucus production, ineffective coughing? Aspiration?
  Measures:
  – Head-tilt and jaw-thrust maneuver
  – Tracheal suction
  – Oxygen
  – Aspiration: Insert naso-gastric tube and empty the stomach
  – Support his chest during coughing
  – Physiotherapy with airway drainage (p. 630)
  – Inhalation of wet mist makes coughing easier

Free airway maneuvers: p. 135.

- Tissue oxygenation: Cyanosis of lips or skin indicates grave hypoxemia.
  Measures:
  – Rule out airway obstruction
  – Oxygen
- Lung auscultation: One-sided poor respiratory sounds 2-3 days after surgery indicate collapse of one lung segment. Within 2-3 more days fever will arise as a sign of pneumonia. Pleural rubbing sounds and localized poor respiratory sounds indicate emboli of one lung artery branch. Moist dependent rales indicate fluid retention in the lung tissue (a total fluid overload or congestive heart failure).
  Measures:
  – Rule out congestive heart failure
  – Reassess the intake-output balance: Fluid overload?
  – Rule out pulmonary vascular embolism
  – Start intensive respiratory exercises to prevent pneumonia
  – Atelectasis/pneumonia: Start or intensify the antibiotic therapy

Antithrombotic therapy: p. 594.

Cardiac failure: p. 590.

Antibiotics – drugs and doses: p. 652-655.

Monitor the circulation. Monitor the fluid therapy

- Intake-output balance: Make a separate list of total fluid intake and output each day for each patient. The list is stuck to the bed and filled in continuously. Check the intake-output balance every 8-12 hours.
- Urine production per hour (UPH): Calculate the mean UPH at least every eight hours. Less than 0.5 ml urine/kg body weight per hour indicates low circulating volume, renal failure, cardiac failure, or urinary tract obstruction.
  Measures:
  – Rule out urinary tract or bladder catheter obstruction
  – Flush a bolus of i.v. fluids (1000 ml) and monitor the urinary response
    Poor response: Try diuretics (frusemide)
- Peripheral circulation: Poor skin capillary circulation with cool feet and hands indicate low circulating volume.
  Measures:
  – Rule out internal bleeding
  – Increase the fluid intake
- Blood pressure and pulse rate: Low blood pressure indicates circulatory shock or cardiac failure. High pulse rate indicates circulatory shock, septic shock, or cardiac failure. Arrhythmia indicates cardiac failure or hypoglycemia.
  Measures:
  – Rule out drug side effect on the heart
  – Rule out cardiac failure

An example: p. 54.

Renal failure management: p. 591.

Degrees of circulatory shock: p. 148.

eptic shock: p. 645.

– Rule out septicemia
– Increase fluid intake

• Monitor drains. Monitor blood loss: Note the volume from each separate drain, whether it increases or not. Increasing limb and abdominal circumference indicates internal bleeding. Spontaneous hematuria, delayed clotting after venous puncture, continuous or secondary bleeding after surgery may indicate coagulation system failure.
  Measures:
  – Rule out poor bleeding control during surgery: Ask the surgeon responsible
  – Do a simple bed-side clotting test
  – Hypothermia causes coagulation failure: monitor body-core temperature, consider central warming to 38 degr.C
  – Consider reoperation to control bleeding

Iypothermia and tendency to bleed: . 131.

Monitor the temperature

Post-operative temperatures around 38 degr.C should be considered normal. Hematomas cause a slight rise in temperature at the time of hematoma resorption. An increasing temperature above 38.5 degr.C indicates infection. Bursts of fever and shivers indicate septicemia or malaria crisis. The typical abscess temperature is varying, the main clinical sign of abscess formation is a worsening general condition.

Immediate measures:
– Post-operative infection/abscess: immediate surgical exploration
– Consider antibiotics
– Rule out other infectious disease
– Malaria crisis: central cooling and antimalarial drugs
– Hypothermia: central warming

Ialaria crisis: p. 288.
he abscess temperature curve: . 459.
entral warming: p. 153.

Monitor the nutrition

• Body weight: Major injury and surgery normally cause water retention and some increase in body weight during the first 3-5 days after injury. Thereafter weight loss indicates protein and fat breakdown.
• Muscular strength: Within 1-2 weeks after major injury/surgery the protein loss should stop and muscle build-up should start. Check muscle bulk and muscle sustainability.
• Wound-healing time: Delayed healing and poor resistance to infections indicate trace element, vitamin or protein deficiency.

he state of nutrition, normal standrds: p. 605-606.
race element deficiency: p. 608.
itamins and trace elements in local odstuffs: p. 616.

Monitor the gastro-intestinal function

• Intestinal bleeding: Massive stress bleeding from the gastric mucosa may occur secondary to major injury/surgery, during septicemia and multi-organ failure.
  Measures:
  – Preventive: Consider antacids in high-risk cases. Sitting/half-sitting position drains acid from the stomach. Early enteral feeding reduces the risk of gastric stress bleeding
  – Curative: laparotomy and bleeding control

omplications of abdominal surgery: . 457.

- Bowel sounds: The abdomen is normally silent for a short period after a major injury. Persistent poor bowel sounds indicate abdominal injury, intestinal hypoperfusion, or abdominal disease.
  Measures:
  – At the time of injury: Intensify the volume therapy and oxygenation to prevent intestinal hypoperfusion and acidosis
  – Rule out endemic diseases that may affect the intestines
  – Early enteral feeding stimulates the intestinal function
  – Missed abdominal injury or abscess formation: Do peritoneal lavage or immediate relaparotomy
  – Paralytic ileus: conservative management

Persisting intestinal acidosis: p. 596.

Endemic intestinal diseases: p. 281.

Peritoneal lavage: p. 109.

- Vomit: Retention of gas and fluid inside the stomach indicates intestinal obstruction or paralysis.
  Measures:
  – Naso-gastric tube suction
  – Identify the cause of retention: Consider relaparotomy
- Measure the abdominal circumference: An increase indicates retention of gas/fluid or abdominal bleeding.
- Stools: Diarrhea and mucus with the stools indicate intestinal inflammation, side effect of broad-spectrum antibiotics or fat overload
  Measures:
  – Rule out endemic intestinal disease
  – Consider stopping broad-spectrum antibiotics
  – Revise the enteral diet

Monitoring enteral feeding: p. 611.

Monitor the mental state

Mental reactions to a major injury tend to follow a basic pattern

- The psychological shock reaction: It lasts some days after injury. The patient is not able to understand information given to him. Indifference and mental depression are common in the shock period. Management: Show patience and kind care.
- The period of confusion: Anxiety, aggression and psychotic reactions are common 1-2 weeks after the injury. Consider these reactions normal. A protracted state of mental depression and indifference is a poor prognostic sign. The management: Start active mental stimulation. Physical exercises may stabilize mental reactions. Consider drug therapy (sedation or psychotropics) in serious cases only.
- The period of reorientation: This period may start 1-3 weeks after injury. The patient starts accomodating himself to the new situation after the injury. The management: Work out a plan together with the patient for his mental and long-term physical rehabilitation. Demand his active participation in daily duties in the clinic and care for fellow patients.

Excessive and permanent confusion with no signs of rational reorientation 2-3 weeks after injury may indicate organ complications. Rule out:
- Missed head injury, or post-operative skull hematoma formation
- Renal failure with electrolyte disturbances and increasing blood urea
- Septicemia, or bacterial embolus to the brain with brain abscess formation
- Depression of the central nervous system as part of a multi-organ failure syndrome
- Drug side effect after repeated anesthesia and analgesia
- The patient may be a drug addict or an alchoholic
- Some endemic diseases (malaria and typhoid fever) may cause mental disturbances

Laboratory and X-ray monitoring

The respiration

he experienced surgeon does well vithout an extensive laboratory ervice, but for training reasons such service is useful.

- Blood gas analysis if available.
- Chest X-ray: Bilateral chest densities appearing gradually after the third day may indicate respiratory failure (ARDS). Density of the lower segments 1-3 days after injury indicates atelectasis.

The circulation and fluid therapy

- Hematocrit: Values of 25-30 are considered optimal. Bleeding cases: The objective of volume therapy is to restore hematocrit to 20-25. Cardiac failure: Hematocrit at 30-35 is optimal.

nemia and surgery: p. 282.

- Hemoglobin: (Except in chronic anemia) a level less than 6-7 g/100 ml normally indicates blood transfusion.
- ECG: ECG patterns may reveal arrhythmias, myocardial ischemia and infarction. The typical ECG patterns of hyperkalemia indicate immediate calcium-therapy and glucose-insulin infusion.

enal failure after soft tissue crush njury: p. 592.

- Serum electrolyte balance: Complex patterns of electrolyte imbalance may be seen after extensive injuries, short-bowel syndrome, burns, multiple infusions and in patients with renal failure. If facilities are present, monitoring of the main serum electrolytes twice a week is helpful:
  - Serum sodium: Deficiency is seen in short-bowel syndrome, prolonged diarrhea and renal failure. Values below 120 may cause mental confusion.
  - Serum potassium: Hyperkalemia may affect the heart. Breakdown of tissue releases potassium into the circulation. If the patient has normal kidney function the release of potassium will seldom be a problem: Beware of cases with renal failure, and the period when the circulation is re-established after prolonged circulatory shock.
  - Serum calcium: Any trauma implies increased losses of calcium, the more extensive the trauma – the higher the losses. Calcium deficiency may cause myocardial dysfunction.
  - Serum magnesium: increased loss after a major injury.
- Serum albumin: Starvation, chronic intestinal infections and renal failure may cause protein deficiency. Low serum albumin is also seen secondary to liver injury, extensive soft tissue injuries, after major burns, and in multi-organ failure. Albumin deficiency may cause tissue edema and a tendency to hypovolemia.

The renal function
- Serum creatinine: A value of 1-1.5 mg/100ml/day is a reliable sign of renal failure. **Notice** that urine production per hour may be normal or increased during certain stages of renal failure.

The coagulation system

Coagulation system failure: p. 593.

- Blood-clotting time: Note the time needed for a venous blood sample to clot in a glass: Clotting time less than 10 minutes indicates that the coagulation function is close to normal. Increased clotting time: Consider low platelet counts, or platelet dysfunction (hypothermia). A rapid dissolution of the blood clot (within less than 20 minutes) may indicate coagulation system dysfunction (DIC).
- Platelet count: Normal counts are 150 000-400 000 platelets/mm^3. Counts lower than 50 000 may cause tendency to bleed after surgery. Counts less than 10 000-20 000 carry risk of spontaneous bleeding. Low platelet counts indicate coagulation system failure (DIC), liver failure, renal failure, septicemia, drug side effects – or most common: bleeding and hemodilution.

The state of nutrition
- Fat content in serum: Centrifuge a blood sample drawn six hours after a standard meal. A whitish opalescent supernatant indicates too much fat in the serum. The reason may be fat overload, or decreased fat metabolism in the liver.
- Transferrin: Transferrin is a protein with a high turnover, synthesized in the liver. It is a good indicator of the body protein synthesis.

Respiratory failure

Post-operative organ failure: Failure that develops in healthy, non-injured organs. One or more organ systems may fail: the lungs, the heart and circulation, the kidneys, the coagulation system, the gastro-intestinal tract, the liver, the central nervous system, the immune system.

Early and late respiratory complications
- Within one week after injury/surgery: acute respiratory failure, lobar atelectasis, pneumonia
- One week to three months after injury/surgery: lung failure (ARDS)

Early complications – risk factors
- Known aspiration to the airways
- Chest injuries
- Upper abdominal injuries

Late complications – risk factors
- Lung contusion
- Multi-injury cases
- Long period of circulatory shock or ischemia
- Cases late for surgery, major post-operative infections, peritonitis, abdominal abscess
- Fractures of pelvis and the long bones
- Multiple blood transfusions (more than 10 units)

Post-operative lung atelectasis and pneumonia

Atelectasis is a state of collapse of the lung tissue in one or several segments of the lung. The common cause is mucus and fluid obstructing the airways. Most often the dependent segments of the lung are affected. Atelectasis normally develops 1-3 days after surgery. The only early sign is localized dull percussion sounds and harsh breath sounds on auscultation. Chest X-rays may give the diagnosis. After some days the collapsed segment is invaded by bacteria – and the pneumonia with fever becomes a fact. Preventive measures:

reathing exercises: p. 630.

- Sitting/half-sitting position improves the ventilation of the dependent lung segments. Get the patient out of bed the first day after surgery if possible.
- Instruct all risk cases to expire against resistance: Blow balloons or surgeon's gloves. The positive alveolar pressure thus created helps prevent atelectasis formation.
- Give effective analgesia and assist the patient with respiratory exercises and coughing to prevent mucus obstruction of the lower airways.
- Perform frequent tracheal suction in patients with poor coughing capacity.
- When the atelectasis is already established: Analgesia with intensive respiratory exercises and repeated tracheal suction may prevent pneumonia formation. At this point extend the antibiotic regime to include gram-negative strains.

o not use potent antibiotics for reventive reasons. Side effects of otent antibiotics: p. 656.

Lung failure – adult respiratory distress syndrome (ARDS)

- Risk case: the patient with labored respiration, respiratory rate higher than 30-35/minute and increasing fatigue. Monitor him closely.
- Confirmed diagnosis: Chest X-rays show a typical picture of "snowstorm" – patchy densities in both lung fields. Imbalance of arterial blood gases with hypoxemia and retention of carbon dioxide confirms the diagnosis.

The optimal management consists of intubation and assisted ventilation on volume-controlled respirator with positive end-expiratory pressure. In a field setting such intensive care is not possible: The management will consist of oxygen, respiratory exercises and analgesia.

The mortality of ARDS is high, even in advanced trauma centers – concentrate on preventive measures

- Early and complete basic life support after the injury.
- A complete regime for respiratory support after surgery: analgesia, early ambulation, respiratory exercises, physiotherapy, tracheal suction and drainage.
- Early high-energy enteral feeding to major injuries.
- Aggressive approach to complications: Reoperate and control bleeding before the circulation collapses; redebride necrotic wounds before an abscess is formed, do relaparotomy for intestinal leak before peritonitis develops, identify and drain abscesses before the general condition worsens.

Circulatory failure

Cardiac arrhythmia, infarction, or myocardial depression may develop at the time of surgery and early in the post-operative period. Or late, as part of a state of multi-organ failure.

Acute cardiac failure (1-7 days after surgery) – the risk cases:
- Lasting circulatory shock and hypoxemia
- Chest injury with heart contusion
- Grave imbalance of electrolytes

Late cardiac failure – the risk cases:
- Septicemia
- Multi-injury cases
- Extensive soft tissue crush injuries
- Extensive burns
- Acidosis
- Protracted recovery with chronic pain and anxiety

Myocardial infarction
The main risk period is during surgery and the first post-operative week. The signs may be chest pain and typical patterns of ischemia on the ECG. **Notice** that the acute infarction may be camouflaged by post-operative pain and fatigue: The only clinical symptom may be arrhythmias and congestive cardiac failure. The management aims at reducing the load on the heart and securing optimal oxygen supply for the heart muscle to minimize the damage. The management consists of effective analgesia, oxygen, respiratory support, early diagnosis and treatment of arrhythmias, and very careful fluid load. The mortality is close to 50% even in the best hands.

Myocardial depression – pump failure
Chemical agents (myocardial depressant factors, MDF) are released from the tissues into the blood circulation after extensive tissue damage, tissue ischemia and acidosis. Pain and anxiety further contribute to MDF release. MDF depresses the myocardial function and reduces the pump effect of the heart. Arrhythmia adds to the pump failure. The clinical picture is congestive heart failure: peripheral edema and dependent moist fine rales on lung auscultation. The management consists of the following:

Myocardial-stimulating drugs are available, but should not be used by inexperienced staff.

Corticosteroids have no place in the management of myocardial depression.

- Acute failure with circulatory collapse: Repeated i.v. doses of ephedrin 0.2-0.3 mg/kg may help maintain the blood pressure. Digoxin 0.25 mg every six hours for 24 hours increases the myocardial performance. In cases with poor drug effect, consider glucose-insulin-potassium infusion: Give glucose 1g/kg + regular insulin 1 unit/kg + 20 mmol KCl as infusion during 10 minutes. The cardiac-stimulating effect lasts for one hour, and the infusion may be repeated.
- Beware of fluid overload: Maintain the hematocrit at between 30 and 35. Anemia due to bleeding is managed with packed red blood cell transfusion.

Monitor the fluid intake-output balance closely: Fluid retention is managed by reduced fluid load and intermittent low i.v. doses of diuretics.
- Beware fluid underload: Poor cardiac output may also be due to low cardiac pre-load, that is a too small circulating blood volume. Documented fluid deficiency (fluid intake-output calculation) and high hematocrit (hemo-concentration) are indicative: Increase the fluid load carefully and see if the blood pressure increases. If not, reduce the fluid load.
- Diagnose and treat arrhythmias early.

Renal failure

Common for all types of renal failure
- Increased serum creatinine level.
- Increased serum urea level.

Acute renal failure
- Causes: necrosis of kidney tissue after hypoxemia or injury to the kidneys.
- Risk cases: protracted circulatory shock, clamping of aorta or the renal artery during emergency laparotomy, urinary tract or catheter obstruction. After extensive soft tissue injury a special type of acute renal failure may develop.
- Diagnosis: decreasing urinary output per hour despite effective volume therapy.

Late renal failure
- Causes: septicemia, or a state of multi-organ failure.
- Risk cases: septicemia, multi-organ failure, renal artery thrombosis.
- Diagnosis: increasing serum creatinine above 1.5 mg/100 ml/day. **Notice:** the urinary output per hour may be normal or increased.

Standards
- Optimal urinary output: 1 ml/kg body weight per hour.
- Oliguria – low urinary output: urinary output less than 15 ml per hour (adult).
- Anuria – no urinary output: urinary output less than 50 ml urine per 24 hours (adult).

Management of renal failure
- Diagnostic: Rule out hypovolemia, cardiac failure and urinary tract obstruction as a cause of oliguria. If X-ray facilities are available, do i.v. urography.
- Diuretics are diagnostic, the objective of diuretic therapy during renal failure is a urinary output of 1.5-2 ml/kg/hour:
  - Mannitol 1-2 g/kg, as i.v. bolus injection during 30 minutes, may be repeated every six hours.

– Inj. frusemide 40 mg i.v., gradually increasing to 80 mg, 120 mg and 160 mg if the urinary response is poor.
- Prevent fluid overload: Restrict the intake of sodium during the early stages of renal failure. Later sodium deficiency may arise due to decreased tubular reabsorption of sodium.
- Beware of hyperkalemia: High serum levels of potassium are common in renal failure. Typical changes on the ECG registration are a late sign of hyperkalemia. Hyperkalemia (more than 6 mmol/l) may cause cardiac failure and should be managed without delay:
  – Calcium chloride 10 mg slowly i.v. stabilizes the myocardium.
  – Glucose-insulin infusion reduces the level of serum potassium (1 g glucose/kg + 1 unit regular insulin/kg).

Special diets for enteral feeding: p. 611.

- Feeding restrictions: The nutrition of patients with renal failure is difficult and should be done under frequent monitoring of renal function and electrolytes. Hypertonic glucose infusions may be used to prevent fluid overload. Low-protein diets should be made for enteral feeding. Special diets for enteral tube feeding to patients with renal failure are available on the market.

Renal failure after extensive soft tissue injury

This special type of renal failure is common – but often not recognized – after extensive soft tissue injuries: mine amputations, major burns, and muscle crush injury. The kidneys are damaged by a particular muscle protein (myoglobin) released from crushed muscle tissue. More than 200 g muscle crushed predisposes to renal failure. The serum concentration of myoglobin reaches a maximum 12 hours after the injury, and signs of renal failure normally develop the first day after injury: red-brown pigmentation of the urine, and decreasing urinary output. Diagnostic: Urine test stix indicates hematuria (myoglobin is a hemoprotein), but urine microscopy shows no red blood cells. The management consists of increased production of alkaline urine:

- Start intensive volume therapy at the site of injury.
- At the clinic, give a mixed infusion of saline-sodium bicarbonate-glucose: The standard infusion is made of 100 ml NaCl 0.9% + 200 ml $NaHCO_3$ 500 mmol/l + 700 ml glucose 50 mg/ml. The infusion rate is 6-7 ml/kg/hour.

Do not use frusemide: It acts on the loop and makes the urine acidic.

- Monitor the urinary response: The objective is to maintain a high urinary output of 5 ml/kg/hour, and alkaline urine with pH above 6.5 for 48-72 hours. Give mannitol infusion 1 g/kg if the urinary production decreases despite the fluid load.
- Monitor the circulation: There is a risk of fluid retention and congestive heart failure, but the risk is small in young patients with normal respiratory and cardiac capacity.
- Monitor the serum potassium – there is a risk of hyperkalemia: To prevent arrhythmia, give i.v. calcium chloride 10 mg (adults) in hyperkalemia higher than 6.5 mmol/l.

Coagulation system complications

The main types of complication
- Increased coagulation causes thrombotic complications, and disseminated intravascular coagulation (DIC)
- Coagulation failure causes tendency to bleed

Risk cases for coagulation system complications
- Lengthy circulatory shock and/or hypoxemia
- Lengthy intestinal hypoperfusion, delayed control of bleeding, poor volume therapy
- Hypothermia due to extensive wounds or lengthy surgery
- Lasting local ischemia (tourniquets, surgery in bloodless field)
- Extensive soft tissue crush injuries
- Fractures of the pelvis and long bones
- More than ten blood transfusions
- Malnutrition and chronic intestinal disease
- Liver injury and liver failure
- Vitamin K deficiency

ntestinal acidosis and multi-organ
ilure: p. 596.

Malnutrition and vitamin deficiencies:
. 604.

Normally the fibrinolysis balances the coagulation
The coagulation system is a continuous complex interaction between two opposing forces: one promoting blood clotting (coagulation), the other promoting blood clot resolution (fibrinolysis). A correct balance between the two forces is essential to normal clotting time, and to maintain the blood fluidity necessary for the capillary blood flow.

After injury the coagulation normally dominates
After injury the coagulation system is modified: The clotting system becomes predominant. Acidosis and tissue hypoxia further increase the clotting tendency. But the injury also activates the fibrinolysis – the more extensive the injury, the bigger the increase in the fibrinolysis. Hypothermia (body-core temperature below 34 degr.C) and grave acidosis (pH below 7.2) may cause general clotting failure.

he problem of hypothermia during
rgery: p. 131.

Monitoring
Clinical monitoring of the circulation, and the bed-side clotting test are sufficient for our use: Leave a venous blood sample for clotting in a plain glass tube bed-side. A clotting time of 10 minutes or less indicates that the clotting system is at a normal level. Clot dissolution within 20 minutes indicates increased fibrinolytic activity: Suspect a state of DIC (see below).

Thrombosis after surgery
- Peripheral venous thrombosis: Clinical signs are localized deep pain, edema and pale-bluish skin. The most common sites for venous thrombosis are the deep veins of the leg, thigh and pelvis.
- Artery thrombosis: Early clinical signs are pale and cool skin and decreased

Artery thrombosis – the management is surgery: p. 190.

capillary circulation distal to the occlusion. Partial loss of neurological function is a late sign.
- Lung embolus: Sudden chest pain and respiratory distress are indicative. Rubbing pleural sounds may be heard on auscultation, blood-stained tracheal mucus may be present. **Note** that the clinical signs may be few in patients in poor general state.

Antithrombotic therapy
- Preventive: Active exercises from the first day after surgery. Get operated patients out of bed the first day after surgery if possible. There is no well-documented effect of preventive drug therapy in injury surgery at reasonable costs.
- Clinical signs of thrombosis – immobilize the patient and start the antithrombotic regime immediately: Give standard heparin 150 IU/kg body weight as an i.v. booster dose. Then a continuous infusion of heparin 300 IU/kg/day in glucose 50 mg/ml. Monitor the tendency to bleed: Stop the infusion in case of bleeding, the heparin effect soon diminishes.

Protamine sulfate is the antidote to heparin, 1 mg neutralizes 100 IU heparin. Protamine sulfate is seldom needed.

Tendency to bleed
The clinical signs are "bleeding from everywhere" during surgery, rebleeding after surgery, delayed clotting after venous puncture or spontaneous hematuria. Consider several causes:
- Low platelet counts: Low platelet counts are normally a sign of increased platelet activation and consumption. A sudden fall in platelets after surgery indicates serious complications: septicemia, abscess formation, DIC, multiorgan failure. Low platelet counts are also seen after multiple blood transfusions, specially where transfusion reactions occur: Expect disturbances in the coagulation system after transfusion of more than the total blood volume (adults: 4-5 liters).
- Platelet dysfunction – normal platelet counts, but poor platelet function: Extensive surgery (especially laparotomies) and major wounds (especially major burns) cause loss of temperature: hypothermia with body-core temperature below 34 degr.C causes platelet dysfunction. Platelet dysfunction may also be seen secondary to renal failure, and as side effect of drugs (sulfa antibiotics, quinine, quinidine, aspirin and indomethacin). Specific therapy is transfusion of fresh whole blood containing normal platelets.
- Protein deficiency: After prolonged starvation, chronic intestinal diseases, liver injury and liver failure, the synthesis of proteins essential to normal coagulation may be impaired. The result is increased fibrinolysis and bleeding tendency. The specific therapy consists of transfusion of fresh plasma or fresh frozen plasma.
- Infections: Vascular wall damage and spontaneous bleeding are often seen in septicemia, meningococcal infections, typhoid fever, and advanced cases of AIDS.
- Vitamin K deficiency: Vitamin K is an essential factor in the clotting system. As a fat-soluble vitamin, the intestinal absorption of vitamin K is impaired in malnutrition, after bile obstruction, bile fistula, and major liver injury/liver failure. Specific therapy: 25 mg vitamin K i.m. for three days.

Fresh whole blood: p. 268.

Disseminated intravascular coagulation – DIC

DIC: formation of multiple blood clots in the capillary circulation.

Special risk cases
- Patients with multiple injuries and extensive surgery
- Serious burns, extensive soft tissue crush injuries
- Persistent wound necrosis
- Septicemia

The diagnosis is mainly clinical suspicion, increased tendency to bleed is the main sign. The clotting test shows increased fibrinolytic activity, and the platelet counts are low due to increased consumption of platelets. The management:
- Manage the predisposing factor as early as possible: eg. improve the tissue oxygenation, redebride wounds, drain abscesses. In most cases the patient will improve without further therapy if the main cause of DIC is controlled.
- In serious cases: Consider vitamin K injections and heparin infusions.

he clotting test: p. 588.

Multi-organ failure

Serious injury cases that survive early complications such as circulatory shock, acute renal failure and pneumonia, are the risk cases for multi-organ failure. **Notice** also that organs which were not damaged at the time of injury may fail. One cannot predict when, which, or how many organ systems will be invoved. The multi-organ failure syndrome may develop one week to three months, most often 1-2 weeks, after primary surgery.

High-risk cases to develop multi-organ failure
- Patients with septicemia
- Patients with post-operative peritonitis or abdominal abscess formation

Common signs of multi-organ failure
- Early – increased capillary permeability: general edema, increased body weight, and high demands for fluid therapy.
- Within some days – hypermetabolism and circulatory signs: increasing heart rate, falling blood pressure.
- Then come the signs of organ failure – which may be two or more of the following:
  – Lungs: respiratory distress, hypoxemia, pulmonary congestion and edema
  – Kidneys: increasing serum creatinine

– Coagulation system: tendency to bleed, DIC
– Liver: jaundice, failure of the protein synthesis, catabolism
– The gastro-intestinal tract: spontaneous ulceration and bleeding
– The immune system: delayed healing of wounds, less resistance to infections, eruption of infection and abscesses in healthy tissue
– The central nervous system: semi-consciousness or coma

The best management is preventive
The mortality of multi-organ failure is above 50% in advanced trauma centers; in a wartime field setting it is close to 100%. Factors that decrease the risk of multi-organ failure:
- Correct early triage of casualties: Identify the cases with high risk of organ failure.
- Basic life-saving support and surgery: Control bleeding by forward surgery to prevent lasting circulatory shock and hypothermia.
- Aggressive monitoring and surgery: Reoperate immediately to debride persistent necrotic tissue, prevent peritonitis, and drain abscesses.

> **Intestinal hypoperfusion – the "motor" of multi-organ failure**
> Lengthy circulatory shock causes hypoperfusion of the abdominal organs. Acidosis of the stomach and intestinal mucosa increases the risk of secondary infections, and accelerates the failure of other organ systems. **Notice** that hypoperfusion and hypoxia may persist in the gastro-intestinal tract – even when the circulation seems well restored after intensive basic life support. Early normalization of the gastro-intestinal function is important to prevent multi-organ failure – that is, oral or enteral feeding, and mobilization of the patient.

We recommend as preventive measures:
- Reduce the duration of acute phase intestinal hypoperfusion: Do one-hour forward surgery to control bleeding in abdominal injuries.

One-hour surgery – why and how: p. 131 and 155.

- Optimal volume therapy: The objective is not only to restore the blood pressure, but to re-establish the peripheral circulation early. Only when the skin is warm and well circulated, the perfusion of the abdominal organs is also re-established.
- Optimal oxygenation: A normal respiratory rate is not good enough. Only when the patient is sitting or half-sitting with painless deep respiration of oxygenated air, can you assume there is no hypoxemia.
- Start enteral feeding the first post-operative day in risk cases: Early intestinal motility and function improve the intestinal blood circulation. And it prevents secondary infections better than do heavy antibiotics.
- Do not use routine antacids to prevent gastric stress bleeding: The acids of the stomach help maintain the normal bacterial flora and function of the intestines. Sitting/half-sitting position and early ambulation drain the stomach and help prevent gastric bleeding.

Side effects of antibiotics: p. 656.

- Restrict the use of broad-spectrum antibiotics: They make it impossible to restore the intestinal function.

Points to note – Chapter 42

Injury and surgery change the need of nutrition
- know how the metabolism is changed: p. 97 and 601
- know the need for glucose, protein and fat: p. 607

Learn to calculate the exact need of energy
- train to use the formula on p. 603
- use the case studies on p. 52 and 609 to formulate a high-energy diet

Learn to compose diets for enteral feeding
- know why oral and enteral feeding is better than i.v. feeding: p. 600 and 612
- know the main food types and their content: p. 616
- train to set up composite diets, study the standard diets on p. 620 and compare with the foodstuff tables on p.621 and 622
- study the teaching cases on p.622 and 623
- note how you avoid thick and sticky feeding solutions: p. 618

Learn how to implement enteral feeding
- learn to insert naso-gastric tubes: p. 139. Note the tube size for enteral feeding
- train, guided by experienced staff, in making a feeding gastrostomy with Foley catheter: p. 369
- study the practical procedure of intermittent enteral feeding: p. 615

Note the precautions during feeding of mal- and undernourished patients: p. 606 and 609

Know how to monitor a feeding program: p. 585 and 611

42 Nutrition after injury and surgery

Why enteral feeding – why home-made diets

Why high-energy nutrition

War casualties often have major or multiple injuries, the risk of post-operative complications is generally high, and the recovery often prolonged. We know that early high-energy nutrition reduces the rate of complications and accelerates the recovery. Thus, a complete casualty management program must also include ways of complete high-energy nutrition. As mass casualties are common, the feeding program should be cheap and simple.

Why enteral feeding

This manual recommends early post-operative enteral feeding as the main method of post-operative nutrition for cases with major injuries:

Intestinal perfusion and organ failure: p. 596.

- Reduced rate of complications: Enteral feeding helps restore the gastro-intestinal function. That stimulates the intestinal blood circulation which in itself reduces the risk of post-operative organ failure.
- Safe and simple: Because the stomach regulates the feeding load, and the intestines regulate the absorption of nutrients, enteral feeding is a safe procedure: Monitoring is simple and can be done without laboratory services. Intravenous feeding contains risky elements, and laboratory monitoring is necessary.
- Low cost and availability: Feeding programs based on commercial solutions are very expensive, and are a waste of money in a setting where casualties are many and resources few. Low-cost, complete enteral-feeding programs can simply be made based on processing of local foodstuffs.

Why home-made diets

There are also political considerations why we recommend home-made feeding solutions: In most Third World areas, local foodstuffs are available that fulfill the requirements for complete nutrition – regarding energy content, balance of nutrients, and contents of minerals and vitamins. In fact, most commercial and expensive feeding solutions are based on foodstuffs common in Third World countries. Among the local population you also find the experts in processing and storing these foodstuffs. There are positive side effects of wartime clinics implementing home-made feeding programs:

Commercial solution: p. 615.

- The local know-how is recognized, and can be utilized in the clinic production of feeding solutions.
- The clinics become better integrated in the local community, which supports the network-strategy of casualty management we recommend in this manual.
- The patient care in general will improve when village health workers and common people are trained in nutrition and feeding programs.

The network model: p. 26.

The complete feeding program

1 Before surgery: Assess the amount of calories needed to fulfill the daily requirements for repair after surgery in each patient, p. 603.

2 Decide the feeding strategy for each patient: oral, naso-gastric tube, gastrostomy tube, or jejunostomy tube feeding, p. 612-614.

3 Prepare the feeding solutions:
- Oral feeding: Study the basic diets for high-energy oral feeding. Prescribe exact diets, the volumes and frequency of meals based on local available foodstuffs, p. 624.
- Tube feeding: Study the basic diets for enteral feeding. Compose your own standard solutions from foodstuffs available, p. 620.
- The viscosity problem: Bulky solutions cannot pass through the feeding tube. They may also cause airway obstruction in oral feeding of children and weak patients. Special methods of food processing solve the viscosity problem, p. 618.

Metabolic response to injury and surgery

udy the basics of physiology: p. 97.

nabolism: the positive metabolic
lance.

atabolism: the negative metabolic
lance.

The normal state of metabolism
- Glucose is the main fuel for the metabolic machinery.
- During hard work or hunger, glycogen from deposits in the muscles and liver is transformed to glucose. After a meal, blood glucose level is restored to normal and the glycogen deposits in the liver and muscle tissue are refilled.
- Excess energy from the meals is used for protein synthesis and stored as fat deposits.
- After prolonged starvation or exhaustion, the body is able to absorb and utilize an increased glucose/carbohydrate load and transform it to glycogen or fat deposits.

Metabolism after injury and surgery
Injury and surgery modify the metabolism in the same way:
- Hypermetabolism: Tissue damage and pain trigger nervous and chemical signals that speed up the metabolic machinery. The energy requirements increase – the body is in a state of hypermetabolism.
- "Self-cannibalism": The body fat deposits and muscle proteins are the main sources from where the body takes energy. The liver transforms fat and amino acids into glucose.
- Modified carbohydrate metabolism: The liver no longer responds to increased carbohydrate intake as "normal": High-carbohydrate diets do not stop the breakdown of fat and protein. In fact, a high-glucose diet after a major injury is dangerous: It may cause liver overload and increase the risk of multi-organ failure.

Factors that stimulate hypermetabolism
- Remaining necrotic tissue after debridement
- Infections and abscess formation
- Pain and anxiety

The best high-energy feeding cannot compensate for these factors. The patient who stays catabolic despite proper feeding, probably needs redebridement, better analgesia, and improved post-operative care.

The three periods of metabolism after injury and surgery

- **Period 1 – relative hypometabolism:** During the first 48 hours after injury, the physiology gradually changes to a state of hypermetabolism. The injury and the surgery cause increased demands on energy/glucose, but the metabolism is not yet able to respond fully to the increased demands: There is a relative hypometabolism. In this period the metabolism cannot utilize high-energy nutrition: Give dilute enteral feeding solutions.
- **Period 2 – hypermetabolism:** The peak of metabolism is reached 2-4 days after injury. At this point the metabolism can utilize high-energy intake: Give a balanced diet of protein, fat and carbohydrates from post-operative day 2 onwards.
- **Period 3 – restore normal metabolism:** How soon protein and fat breakdown stops and normal metabolism is restored depends upon the injury, the quality of surgery – and also on the nutrition. The better the energy intake matches the energy requirement in each patient, the sooner normal metabolism is restored.

Multi-injury cases, extensive soft tissue loss, burns, and post-operative infections cause the energy requirements to stay high for weeks.

Early basic life support and surgery reduce the duration of period 1.

Persisting catabolism may be fatal
If the body remains in a state of hypermetabolism without high-energy intake, weight and muscle mass are lost, electrolyte imbalance and vitamin deficiencies develop: There is increased risk of multi-organ failure.

The objective of post-operative feeding programs
As soon as possible after major injury and surgery:
- Stop catabolism: Weight loss and muscle waste are indicators.
- Restore anabolism: Weight gain, muscle strength and an uncomplicated healing of wounds are indicators.

Post-operative edema may increase the body weight and hide signs of catabolism.

Calculate the basic energy demand and the stress level

A patient with a moderate injury has a moderate increase in energy consumption: He is under moderate stress. Patients with major injuries or with post-operative complications are under heavy metabolic stress. To plan the feeding program:
- Calculate the basic energy expenditure (BEE) for the actual patient.
- Assess the stress level: Add to the BEE the energy required due to the degree of injury and/or complications.

The basic energy expenditure – BEE

> **BEE:** The amount of energy necessary to maintain vital functions – respiration, circulation, function of the brain etc. BEE depends on body size and age, and is measured in kilocalories (kcal) per 24 hours.
>
> $$\begin{aligned} BEE = 66 &+ (\text{body weight} \times 13.7) \\ &+ (\text{body height} \times 5) \\ &- (\text{age} \times 6.8) \end{aligned}$$

An example

You are planning a program for post-operative feeding of a patient 20 years old, with a weight of 70 kg, and 175 cm height.

$$\begin{aligned} BEE = 66 &+ (70 \times 13.7) \\ &+ (175 \times 5) \\ &- (20 \times 6.8) \\ &= \text{approximately } 1700 \text{ kcal/24 hours} \end{aligned}$$

Add for the actual stress level

- Stress level 1: moderate injuries without secondary complications, smooth secondary surgery in uncomplicated cases. The actual energy expenditure = BEE × 1.3
- Stress level 2: extensive injuries and extensive surgery. The actual energy expenditure = BEE × 1.5
- Stress level 3: multiple injured, serious burns, repeated surgery, serious infections and sepsis. The actual energy expenditure = BEE × 2.0

Our patient in the example above has an extensive soft tissue injury; repeated skin grafting is done. Consider him a stress level-2 case: The actual energy expenditure is 1700 × 1.5 = 2550 kcal/24 hours.

Add for exercises and temperature

So far we considered the patient to be staying in bed, doing nothing, in a temperate climate, with a normal body temperature. Add to BEE:

- The energy used for exercises or working: 1000-1500 kcal.
- For fever/hyperthermia: The BEE is increased by 7% for each centigrade the body temperature rises above 37 degr.C.

In the example above: Our patient has an extensive soft tissue injury, the body temperature is normally about 38 degr.C in non-infected major injuries. He is doing daily exercises. Add: 1000 kcal + (1700 kcal × 0.01 × 7) = 1120 kcal/24 hours. So the total energy consumption is:
2550 + 1120 = about 3700 kcal/24 hours until the wounds have healed.

Alternatively, instead of calculating the degrees of fever and activity, you may just add 25% to the actual energy requirement. In this case that makes 2550 kcal + (2550 × 0.01 × 25) kcal = 3200 kcal/24 hours which should be the minimal content of energy in his diet.

Malnutrition complicates surgery

> Malnutrition and extreme exhaustion are risk factors regarding anesthesia, surgery and recovery. Evaluate the nutritional state **before injury** – especially in areas where chronic intestinal diseases are endemic.

A soldier injured after days of fighting is physically exhausted, he is in a catabolic state: The glycogen deposits are emptied, the liver maintains the level of blood glucose by producing glucose from body fat and proteins. Patients in a state of malnutrition after lasting starvation or lack of protein have much the same metabolism as the exhausted soldier: They are "eating" up their own body proteins and fat deposits. **Why malnutrition is a risk factor:**

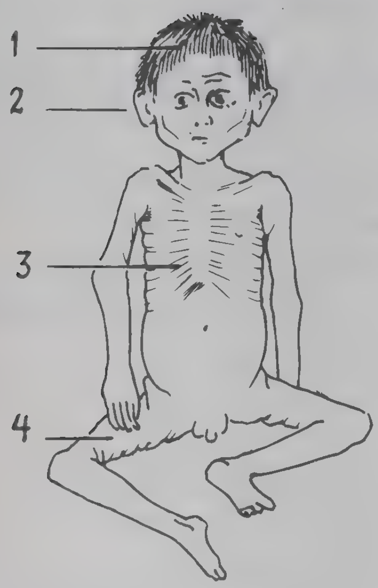
- Electrolyte imbalance may complicate the anesthesia and cause circulatory failure.
- Protein deficiencies may affect the coagulation system and cause a tendency to bleed.
- Low counts of blood platelets are common.
- The period of hypermetabolism after injury and surgery will probably be prolonged and the risk of post-operative organ failure increased.
- Associated anemia, vitamin and mineral deficiencies delay the wound healing.
- The immune system is weak, the risk of infections increased.

Clinical signs of malnutrition

Vitamin deficiency

- The skin and mucosa are thin, vulnerable, with tendency to bleed.
- Loss of hair. Nails break easily.
- Loss of muscle mass. The legs are painful, weak, often with neurological signs.

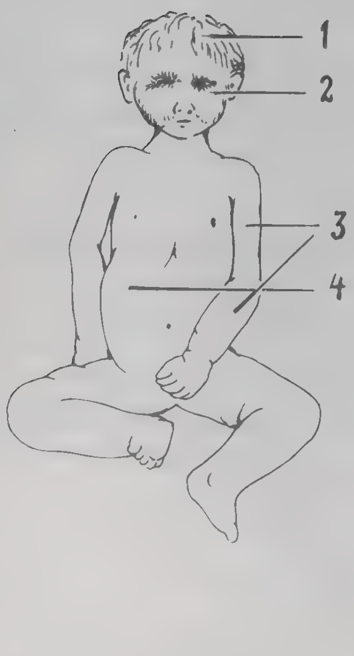
1



1 Marasmus – malnutrition caused by prolonged low-energy nutrition

1 – normal hair
2 – "old man's face"
3 – no subcutaneous fat
4 – wasting of muscle and/or weak muscles

2



2 The typical kwashiorkor patient, a result of prolonged state of protein deficiency

1 – thin hair
2 – general edema
3 – thin upper arm (muscle wasting) and swollen forearm (edema)
4 – big belly (large liver and intraperitoneal fluid). Protein deficiency is easily recognized in children. But in adults the clinical signs are few, and a serious condition of protein deficiency may be missed unless you make it a routine to look for it

3 The mid-upper arm circumference (**MUAC)** indicates the degree of muscle wasting.

Table 1
The normal values of the MUAC for males

Age (years)	MUAC (cm)	Age (years)	MUAC (cm)
1-2	12.7	15-16	23.7
3-4	13.7	17-18	25.8
5-6	14.7	19-30	27.5
7-8	16.0	30-40	28.3
9-10	17.0	40-50	28.3
11-12	18.3	50-60	28.0
13-14	21.1	60-70	27.0

Table 2
The normal values of the MUAC for females: Until 15 years of age, the MUAC is identical for boys and girls

Age (years)	MUAC (cm)
15-16	20.2
17-18	20.5
19-30	21.0
30-40	21.5
40-50	22.0
50-60	22.5
60-70	22.5

4 The triceps skinfold: The thickness of the triceps skinfold indicates loss of subcutaneous fat. Measure it with standardized calipers.

Table 3
The normal values of the triceps skinfold for males

Age (years)	Skinfold (mm)	Age (years)	Skinfold (mm)
1-2	10	15-16	9
3-4	10	17-18	8
5-6	9	19-30	11
7-8	9	30-40	12
9-10	10	40-50	12
11-12	11	50-60	11
13-14	10	60-70	11

Table 4
The normal values of the triceps skinfold for females

Age (years)	Skinfold (mm)	Age (years)	Skinfold (mm)
1-2	10	15-16	17
3-4	11	17-18	19
5-6	10	19-30	19
7-8	11	30-40	22
9-10	13	40-50	25
11-12	13	50-60	25
13-14	15	60-70	24

Table 5
The standard body weight corresponding to body height for children, both sexes combined. A weight below 80% of the standard indicates that the child is undernourished.

Height (cm)	Weight (kg)	Height (cm)	Weight (kg)
75	9.8	95	14.3
80	10.9	100	15.6
85	12.0	110	18.4
90	13.1	120	22.0

Laboratory examination

It may reveal malnutrition and mineral deficiencies. If available, check as a routine the hemoglobin, serum electrolytes, serum creatinine, serum albumin, the liver function.

Feeding strategy in malnutrition cases

The injury case needs 3-4 g glucose/kg/24 hours. The undernourished patient can utilize 6-7 g glucose/kg/24 hours.

- **Step one – restore the liver glycogen deposit:** The liver glycogen deposit in an adult corresponds to 2000 kcal. As metabolism of 1 g glucose makes about 4 kcal, the patient needs about 500 mg glucose to fill up the liver store. Add the daily requirement of 200-300 mg glucose. In order to shift the metabolism into a state of protein and fat synthesis, he also needs a high-energy balanced nutrition of protein and fat.
- **Step two – turn the state of catabolism into a state of protein synthesis:** In injury cases not complicated by lasting hypoglycemia or starvation, we normally start high-energy nutrition from post-operative day 2 or 3. In undernourished cases we recommend high-energy nutrition as soon as possible after the injury and surgery.

The feeding program (adults)

Glucose infusion before surgery: p. 152.

- Consider starving patients at least as stress level-2 cases: The actual energy consumption is BEE × 1.5.
- Glucose: Give 400-500 mg for the first 3-4 days, then reduce the glucose intake to the normal level of 200-300 mg per day.

- Protein: The daily intake should be 100-120 g/day.
- Fat: The rest of the energy needed is covered by intake of fat.
- Treat imbalances of electrolytes immediately.
- Give vitamins and trace elements from the first day after injury.
- Consider blood transfusion if the hemoglobin is less than 6-7 g%.

rgery in patients with chronic ane-
ia: p. 282.

Consider early high-glucose feeding a part of the basic life support to very exhausted and/or undernourished war casualties: Start before surgery, continue after surgery.

lucose in basic life support: p. 152

Planning post-operative nutrition

nese recommendations are valid for
e non-undernourished patient.

ne basic carbohydrate is glucose.

ne nitrogen excretion in the urine
dicates the protein breakdown. The
ily normal excretion of nitrogen is
out 0.1 g nitrogen per kg body
eight. 1 g nitrogen is equivalent to
25 g protein.

Carbohydrate requirements
The normal glucose requirement is 2 g/kg/24 hours: An adult of 70 kg needs about 140 g glucose a day. After injury the requirements are increased to 3-4 g glucose/kg/24 hours: A patient of 70 kg needs 200-300 mg glucose per day.

Protein requirements
The daily requirement of protein is 1.25 g/kg, that is, 70-90 g for an adult. Under metabolic stress the requirement is increased to 1.3-1.4 g/kg/24 hours. There is no use giving protein or amino acids exceeding the calculated requirement: You cannot shift the breakdown of body protein into a positive protein balance with intensive protein feeding only. High-energy feeding with a balanced intake of carbohydrate, protein and fat is the only way to stimulate anabolism.

Fat requirements – energy requirements
Fat is the most potent source of energy. Compare the approximate energy produced by metabolism of glucose, protein and fat:

1 g carbohydrate → 4 kcal
1 g protein → 4 kcal
1 g fat → 9 kcal

The increased energy requirements of patients after trauma can best be met with diets rich in fat: Let the amount of protein and carbohydrate be constant, and set the amount of fat according to their energy requirements. You may give as much as 50% of the non-protein calories as fat, in undernourished patients even 60% may be utilized.

There is regularly increased losses of calcium and magnesium after a major injury.

Mineral requirement

It depends upon the losses, which vary from case to case: An ileostomy case loses much sodium. Patients with intestinal fistula or renal failure may develop a complex picture of electrolyte/mineral imbalance. Concentrate on sodium (Na), potassium (K), calcium (Ca), and chloride (Cl). When enteral nutrition is used, the body absorbs minerals from the intestine according to its requirements. This makes enteral feeding more effective and less risky than intravenous infusion of minerals.

Table 6
Daily basic requirement of minerals (adults)

Na	2-3 g	86-129 mmol
K	2-4 g	26-52 mmol
Ca	800 mg	11.2 mmol

Trace minerals: minerals needed in very small amounts. The most important are iron (Fe), magnesium (Mg), copper (Cu), zinc (Zn), and iodine (I).

Endemic vitamin deficiencies: p. 284.

Vitamin and trace mineral requirements

Normal levels of vitamins and trace minerals are essential to the patient's rehabilitation after injury. In some areas as certain vitamin deficiencies are endemic, the requirements may thus vary much from one population to another. Most deficiencies of vitamins and trace minerals develop 1-3 weeks after injury/surgery. Of the trace minerals, iron is essential to hemoglobin synthesis and zinc seems to play a role in connective tissue metabolism and wound healing.

Table 7
Daily requirements of vitamins and some trace minerals (adults)

Thiamine	2.8 mg	Magnesium (Mg)	300-400 mg
Riboflavin	4.2 mg		3.2 mmol
Nicotinamide	28 mg	Iron (Fe)	10-20 mg
Vit B6	4.6 mg		(of which only
Folic acid	0.4 mg		10% is absorbed
Vit C	140 mg		from the intestine)
Vit A	0.7 mg	Zinc (Zn)	15 mg
Vit D	2.8 picog	Iodine (I)	150 picog
Vit K	0.15 mg	Copper (Cu)	2-3 mg

Vitamins and minerals in common foodstuffs: p. 616.

Minerals and vitamins
In enteral feeding, the requirements are fulfilled using a balanced diet of vegetables, cereals, animal protein and fat. Give tablets of iron as soon as the intestinal function is restored.

ntravenous nutrition? This case vould daily need 1500 ml 20% fat emulsion – a daily cost of US$100-50 for the fat nutrition only!

To set up the enteral feeding diet: p. 620.

An example: a plan for post-operative nutrition

The patient is a 20-year-old man in a state of good nutrition, of height 175 cm, and weight 70 kg.

- **Step 1 – calculate the BEE**
  BEE = 66 + (70 × 13.7)
  + (175 × 5)
  – (20 × 6.8)
  = approximately 1700 kcal/day
- **Step 2 – assess the stress level and calculate the total energy requirement:** Our patient is a multi-injury case with double open femur fractures and penetrating chest injury. The primary operation was time consuming, and you plan another operation for fixation of the fractures within 4-5 days. You consider him a stress level-3 case. The actual energy requirement is 1700 × 2 = 3400 kcal/24 hours. As a rule we add another 25% to this value (for hyperthermia, physical activity):
  Total energy requirement = 3400 + (3400 × 0.01 × 25) = about 4300 kcal/24 hours
- **Step 3 – calculate the daily glucose requirements:** As he is not undernourished, the daily need is
  4 g glucose/kg = 70 × 4 g = 280 g glucose/24 hours.
- **Step 4 – calculate the daily protein requirements:** He is not undernourished, the daily protein requirement (major injury) is
  1.4 g/kg = 1.3 g × 70 = 100 g protein/24 hours.
- **Step 5 – calculate the calories from glucose and protein:** Both glucose and protein yield about 4 kcal/g in metabolism.
  280 g glucose → 280 × 4 = 1120 kcal/24 hours.
  100 g protein → 400 kcal/24 hours.
  Thus the total amount of energy from glucose and protein is
  1120 kcal + 400 kcal = about 1500 kcal/24 hours.
- **Step 6 – calculate the fat requirements:** He needs a total of 4300 kcal/24 hours, and 1500 of these are fulfilled by glucose and protein administration. Thus 4300 – 1500 = 2800 kcal/24 hours must come from fat. Metabolism of 1 g fat yields 9 kcal. Thus he needs: 2800 ÷ 9 = about 300 g fat/24 hours to meet the extreme energy requirements.
- **Conclusion – a plan for the post-operative nutrition:** His nutrition must contain 280 g glucose, 100 g protein, and 300 g fat per 24 hours. This will give a total energy output of about 4300 kcal/24 hours. Study Tables 9-12, p. 621 and compose the diet he needs.

Factors that modify the standard plan

Malnutrition and starvation before injury

Increase the daily intake of carbohydrates to 6-7 g/kg/24 hours for the first few days after injury/surgery. Protein deficiency is common after prolonged starvation: So increase the daily protein intake to 2 g/kg/24 hours for some days.

Chronic gastro-intestinal disease before injury

Beware of major imbalance of the electrolytes. Protein deficiencies are also common. Consider high-protein and high-calorie nutrition after injury.

Short-bowel syndrome after surgery

Short bowel occurs after a stoma of the small intestine or of the proximal part of the large intestine that excludes the distal parts of the intestine.

- Electrolyte deficienciès: Sodium, magnesium and calcium are lost through the stoma in amounts giving rise to clinical symptoms of deficiency.
- Loss of water and water intoxication: The colon normally plays a role in the regulation of the body fluid balance, as water is absorbed from the colon into the circulation. In short-bowel syndrome, the water absorption is partly lost: The short-bowel patient feels thirsty, drinks more and more water which causes dilution of serum sodium. A state of weakness, drowsiness and serious electrolyte imbalance called "water intoxication" may develop. Early intake of salt and protein is preventive.
- Cannot utilize fat: In cases with the stoma proximal on the small intestine, the fat absorption is poor. Deficiency of the fat-souble vitamins (A, D, E and K) may develop unless vitamin supplements are given.
- Cannot tolerate fat: Patients with short bowel develop diarrhea on high-fat diets. The diarrhea may add to the electrolyte disturbances. Reduce the fat intake to less than 100 g/day or completely exclude fat from the diet.

Intestinal dysfunction due to side effects of broad-spectrum antibiotics is common: Stop the misuse of potent antibiotics for preventive reasons, see p. 656.

Gut perforations, peritonitis and intestinal fistula formation

These complications have in common the fact that electrolytes, water and protein are lost from the intestines. The daily losses are moderate, but the long-term total losses may be considerable. There is no predictable pattern regarding the deficiencies: Assume that sodium, potassium and chloride are lost from the intestines. You may safely increase the sodium, potassium and chloride intake to 50-100% above the standard.

Standard mineral requirements: Table 6, p. 608.

Vomiting

The main problem is fluid loss: Note the approximate volumes of fluid lost, and make an intake-output card for each 24 hours. Chloride is lost, often in considerable amounts: If you do not have laboratory facilities, increase the intake of sodium and chloride.

Burns of 20% body surface area or more

The metabolic requirements in major burn cases differ somewhat from other injuries:

- The hypermetabolism develops slowly
- The hypermetabolism may last for months
- Considerable fluid and electrolyte imbalance may develop
- Large amounts of protein are lost through the wide wounds

For details: p. 560.

Protracted recovery

Repeated surgery, elaborate secondary and reconstructive surgery, long-term immobilization in bed, chronic pain, psychological depression causing inactivity – these are all factors that prolong the period of catabolism and increase the losses of body fat and protein.

As a rough rule: Continue high-energy nutrition until all wounds have healed and the patient is out of bed.

Infection and septicemia

The metabolic changes associated with septicemia are profound.

- Due to the fever, the energy expenditure is increased by 7% for each centigrade of hyperthermia.
- The septicemia itself causes further hypermetabolism: The actual energy expenditure is approximately 100% higher than BEE.

Post-operative organ failure

The metabolic response to secondary organ failure is complex, and differs from case to case. The main guidelines to follow:

enal failure: p. 591.

- Renal failure: The capacity of fluid and electrolyte regulation is impaired. Reduce the overall fluid load. Reduce the intake of sodium and potassium. Reduce the protein load.

ulti-organ failure: p. 596.

- Liver failure and multi-organ failure: The capacity of fat metabolism is reduced. Reduce the intake of fat to 100 g/24 hours, or less.

espiratory failure: p. 588.

- Respiratory failure: The lung excretion of carbon dioxide is reduced. Acidosis may develop unless the total energy load is generally reduced.

Monitor the nutrition

In most cases, major cases included, close bed-side monitoring of clinical signs is good enough when enteral feeding is done – provided the basic precautions are followed. Let one and the same experienced paramedic take care of major cases: Thus discreet clinical signs and minor alterations are identified early, and the feeding modified accordingly.

Monitor the general condition

- Delayed recovery, delayed wound healing and recurrent infections indicate insufficient nutrition.
- Note the mental state: Depression, indifference or unrest may indicate trace mineral deficiency.

serious zinc deficiency delayed ound healing and dermatitis deve- p.

- Look for neurological symptoms: Confusion, drowsiness, partial loss of sensory function and spasms may indicate deficiency of magnesium, phosphate or calcium.

Weight loss or weight gain

- Water retention: Water is stored as edema during the first few days after injury; the body weight may increase.
- Weight loss: During the 1-2 weeks after injury/surgery there is normally a certain weight loss. In major injuries a weight loss of 10% of the total body weight may be considered acceptable. But losing more than 25% of the initial body weight is a poor sign that indicates high mortality risk.
- The objective: Within one week after the primary surgery, the patient should stabilize the weight and gradually gain weight if the nutrition is appropriate.

Muscle strength – muscle sustainability
- Strength: Monitored daily by the same paramedic, it is possible to note whether the patient's muscular strength increases or decreases.
- Just as important is the muscular sustainability: Let him do repeated simple exercises and note how many times he is able to perform them. Poor performance reflects a poor general condition/catabolism.

Lack of phosphate and magnesium deficiency may cause blurred vision, mental confusion and trembling.

The central body temperature
Intolerance to nutrients may cause fever. Patients on long-term, high-energy nutrition may develop intolerance to nutrients.

The fluid balance
Register the total fluid output: urine, loss from wounds, bandages, drains, fistula and stoma. Fever increases fluid loss by evaporation. Make a 24 hours' intake-output card for each patient to monitor the fluid balance and urinary output.

Monitoring the fluid balance and renal function: p. 584.

The circulation
- Fluid retention: Do daily lung auscultation to identify pulmonary fluid retention. Soft tissue edema of the legs is another indicator.
- The heart rate and regularity: Calcium and potassium disturbances may cause arrhythmia.

Monitoring the circulation: p. 584.

Fat overload
- The most common sign is diarrhea and vomiting.
- Serum examination: Take a blood sample six hours after feeding. Centrifuge it (1200 rounds per minute) and study the supernatant: If it is milky and opalescent, the fat content is too high.

Monitor the practical feeding procedures
- Check the production: that the diet contains what is prescribed and promised.
- Check the suspension of nutrients: that it is not contaminated.
- Check the feeding tube: that it is not displaced or obstructed.

Enteral feeding

Methods of feeding after surgery

Why not intravenous feeding
- Oral and enteral feeding is more effective, cheaper, is safe, and the nutrients can be found everywhere.
- The commercial i.v. solutions are too expensive: A complete feeding program for one patient costs US$100-200/24 hours.
- The feeding solutions and additives (minerals, trace elements and vitamins) are not readily available in a field wartime setting

- I.v. feeding is risky: The complete program includes mineral additives; if used incorrectly they may cause serious complications.
- Close laboratory monitoring is necessary.
- I.v. lines do become infected, a big problem.

Types of enteral feeding

- Oral feeding should be the standard method for low-risk cases. It is the safest method. The preparation of diets is simple.
- Naso-gastric tube feeding should be the standard method for cases that need early high-energy nutrition, where you reckon the recovery to be uncomplicated and rapid. The method is safe, but the preparation of diets elaborate: Tube feeding solutions must have low viscosity and cannot be bulky.
- Gastrostomy with gastric tube feeding should be the standard method for high-risk cases that need early high-energy nutrition, where you suspect the recovery to be slow and/or complicated. The preparation of tube-feeding solutions is elaborate.
- Jejunostomy tube feeding should be used in high-risk cases where gastric feeding cannot be done due to upper abdominal injury and surgery. Jejunal tube feeding carries higher risk of medical and technical complications.

ide effects of duodenal and jejunal eeding: p. 614.

Oral feeding and i.v. fluid therapy

- Conditions for oral feeding: (1) The patient can take oral soft food without risk of aspiration. (2) He is not a high-risk case that needs high-energy nutrition from post-operative day one.
- The day of surgery: Give sips of orange juice-water. Add i.v. 2000 ml Ringer and 1000 ml glucose 50 mg/ml as standard fluid therapy to adults. Add extra for bleeding and increased losses. Add glucose (concentrated infusions) to hypoglycemic and undernourished patients. (see p. 152 and 606).
- Post-operative days 1 and 2: When there are bowel sounds, start oral feeding with soups and pastes made from local foods. Initially the meals are small; increase the volumes stepwise. Frequent small meals (every 1-2 hours) are better than a few big ones. Also feed during the night in major cases. Normally the patients can take 1000-2000 ml/day. Monitor the intake-output fluid balance and give i.v. fluid supplements if needed. The energy content should be high, the diet well balanced in carbohydrate, protein and fat. Avoid fried food; well-boiled food is better digested. Use clean, boiled water in the preparation of the meals.
- Precaution – risk of aspiration: Delay oral feeding if there are no bowel sounds, if the patient vomits or if there is increasing abdominal distention. Except in high-risk cases, a healthy young patient can do with only i.v. fluids until post-operative day 4 or 5.
- If oral or naso-gastric tube feeding do not work 4-5 days after surgery, consider laparotomy: There may be a missed abdominal injury, or complications of abdominal surgery.

ssess the risk of post-operative comlications: p. 98.

Composition of high-energy diets for ral feeding: p. 624.

Naso-gastric tube feeding

Introduction of the naso-gastric tube: p. 139

We recommend large-bore naso-gastric tubes both for gastric suction and decompression before surgery, and for feeding after surgery. Tube diameters of 5 mm make feeding easy, but they may be uncomfortable to the patient: Pain and pressure wounds of the nose may develop within some days. Fine-caliber tubes, of diameter 3-5 mm with wire introducer are convenient to the patient: He may even drink or eat along the introduced fine-caliber tube. But the thinner tubes often become obstructed during feeding if they not frequently irrigated. We recommend large-bore tube for intermittent feeding, and shift to gastrostomy feeding if the patient or the staff has too many problems with the naso-gastric tube, or if the recovery becomes lengthy.

Naso-gastric feeding is superior to naso-duodenal feeding

- Contamination: The gastric acid acts as a protective barrier against bacteria and infection. So a slightly contaminated gastric meal does not necessarily cause enteritis. Duodenal or jejunal feeding is vulnerable to infection and enteritis: The meals must be prepared under very clean conditions, stored well and not be contaminated.
- Overload: In gastric feeding, the pylorus regulates the duodenal load, letting only small intermittent volumes of food pass into the intestine. Feeding directly into the duodenum/jejunum may cause vomiting, intestinal distention and diarrhea if the load is too high.

Gastrostomy tube feeding

Planning the post-operative management starts with a rough risk assessment before and during surgery.

How to do the tube gastrostomy: p. 369

Do the tube gastrostomy at the time of primary surgery in all cases with high risk of post-operative complications, protracted recovery or malnutrition. Do secondary gastrostomy in patients who come up with complications, where the post-operative recovery will be slow: The gastrostomy operation is rapid, simple, and done under ketamine anesthesia. Normally gastrostomy feeding is well tolerated and convenient for the patient as well as for the nursing staff. There are no objections to out-patient management. **Precautions:** Initial confusion may make the patient withdraw the tube: Fix it well with adhesive tape.

Jejunostomy tube feeding

The proximal loop of jejunum is intubated in the same way as the gastrostomy is done. Make a separate small stab incision in the abdominal wall, and a very small stab incision through the jejunal wall: A wide intestinal incision may leak along the catheter. Introduce a Foley bladder catheter size 18; inflate the balloon with not more than 5 ml of water. Take care that the balloon does not obstruct the intestinal lumen. There are several technical complications to jejunal tube feeding:

- Leaking along the catheter may cause stoma infection or fistula formation.
- The catheter may withdraw spontaneously.
- The catheter may become displaced inside the intestine, become obstructed/angulated, or obstruct the intestinal lumen.
- The complications are more common in patients whose general condition is poor: If you decide on jejunal feeding, make the jejunostomy early and before the general condition worsens – best during the primary operation.

Percutaneous needle jejunostomy can be done: It has less complications, but the fine-caliber tubes can only take specially prepared fluid solutions.

The feeding procedure

The alternatives:
- Low-cost: intermittent bolus feeding of home-made solutions
- High-cost: continuous feeding of commercial solutions

Intermittent enteral bolus feeding
Intermittent feeding can be done through naso-gastric, gastrostomy or jejunostomy tubes. Intermittent feeding is safe and simple: Prepare volumes of feeding solution for 24-48 hours' use, store them cold to prevent contamination (in refrigerator). Collect only a minor sample before feeding hours, warm it to reduce the viscosity. Inject the feeding solution in the tube with a large syringe, the patient in half-sitting position, left side elevated.
- The day of surgery: Start careful feeding with orange juice-water, 50 ml every hour. Add 4-6 g salt/24 hours.
- Post-operative day 1: Give dilute high-energy solution 50-100 ml every hour, increase the concentration and volumes stepwise.
- Within 2-4 days meals of 200-600 ml concentrated high-energy nutrients are injected 6-12 times a day.
- Monitor the intake-output balance: Additional i.v. infusions of electrolytes and fluid may be needed.

Vomiting and diarrhea: Consider overload, tube displacement, too concentrated solutions, or contaminated nutrients.

Continuous enteral feeding
Fine-caliber naso-gastric or jejunal tubes can only take low-viscosity, commercial solutions. **Precautions:** Irrigate the tube frequently with water to prevent obstruction. The infusion set is changed each day to avoid contamination. The bottle containing the nutrients should not be kept in room temperature for more than six hours in order to reduce the risk of contamination.

The first infusions should not exceed 50 ml/hour, the rate being gradually increased to 200 ml/hour.

Table 8
Contents of a commercial solution for enteral feeding, per 100 ml

Osmolality	200	Pantothenic acid	0.5 mg
Energy content	100 kcal	Vit C	5 mg
Protein	4.5 g	Calcium	90 mg
Fat	3.5 g	Phosphorus	75 mg
Carbohydrate	12 g	Sodium	95 mg
Vit A	60 picog	Potassium	160 mg
Vit D	0.5 picog	Magnesium	15 mg
Vit E	1.5 mg	Iron	1.1 mg
Thiamine	0.1 mg	Copper	0.1 mg
Riboflavin	0.1 mg	Iodine	7.5 picog
Vit B6	0.12 mg	Zinc	0.8 mg
Niacin	1 mg	Manganese	0.2 mg
Folic acid	20 picog	Chloride	160 mg
Vit B12	0.3 picog		

Objections to commercial solutions for enteral feeding:
- The composition: The energy from carbohydrate constitutes about 50% of the total energy in this solution, which is not optimal for major trauma cases.
- The cost: Complete nutrition for one patient costs about US$150/24 hours.

Common foodstuffs and their nutrient value

Not only copy the pharmaceutical products – but improve them

Most ingredients of the commercial preparations of enteral solutions use common foodstuffs from Third World countries. The commercial solutions have consistency (viscosity), concentration (osmolarity) and contents specially adapted to enteral tube feeding. However that adaptation can just as well be done in the kitchen of any wartime clinic using home-made feeding solutions. The advantages of feeding home-made diet:
- **Better tolerance:** Among different populations, the intestinal tolerance for types of food differ. This is partly due to the intestinal bacterial flora, partly due to physiological differences, partly due to cultural habit. The most effective feeding is based on the foodstuffs your intestine knows from childhood on – and not on some unfamiliar international standard.
- **Education in general health:** Invite those with "know-how" among the local population to participate in developing local feeding programs – to identify the basic foodstuffs, and to draw up a program on processing and storage. To coordinate this, the wartime surgeon himself should have a basic understanding of nutrition and local foodstuffs.
- **Low costs make for self-sufficient clinics:** To overcome problems of logistics and shortage of funding is the most positive effect of local production of feeding solutions.

The locally made feeding solutions should also be used in village health care, in the management of malnutrition and chronic diseases.

Cereals and grains – a main source of carbohydrates

Where sugar or honey is expensive or not available, cereals and grain are the main sources of carbohydrates for nutrition. Grain is milled to flour, cereals may be dried and milled to flour. **Notice:** The milling process may extract valuable trace elements, vitamins and protein from the grain: Refined rice, for instance, is easily digestible but has lost many important nutrients. Dry whole grain and whole flour contain no vitamin C, but are important sources of vitamin B, calcium and iron. White maize flour is a poor source of protein: In local traditions it is mixed with bean products to make a protein-rich diet.

Milling and loss of nutrients: p. 618.

A special problem with the solutions of cereals and flour used for enteral feeding is the high viscosity of the cooked water suspensions: Cereals contain starch that makes the suspension thick and increases the viscosity during cooking and cooling. This problem can be solved by controlled fermentation: p. 618.

Tubers and roots – alternative carbohydrate sources
Tubers and roots (banana, potatoes, cassava, plantain) contain much starch that makes suspensions bulky and gives high viscosity. They are optimal for feeding solutions, but should be used when better carbohydrate sources are not available. Most roots and tubers contain vitamin C. They are poor in protein.

Legumes (beans and peas) – important sources of energy
Legumes are among the main sources of both protein and energy. Being easily available and often included in local cooking traditions, they should be the basic ingredients in home-made diets for enteral feeding. They may be stored after drying and ground to flour. Legumes with high-fat content (soy beans, groundnuts) may produce oil with high-energy content. Legumes are important sources of vitamin B, folic acid, calcium and iron. The young sprouts are also rich in vitamin C.

ll fresh legumes contain a certain nount of toxins which are destroyed ter boiling or soaking.

Oilseeds and nuts – alternative energy sources
These foodstuffs are rich in fat, some of them also in protein (melon seed, sesame seed). Use flour made from seeds and nuts as additive to the basic diets in cases that need very high-energy intake. For example, ground white coconut may be mixed with white cereal flour to increase the energy content as well as digestibility.

il from melon and sesame seeds is ed in commercially made suspenons for enteral feeding.

Vegetables and fruits – sources of vitamins and trace elements
In most areas some kinds of vegetables or fruits are available. The darker the color of the fruits (green or yellow), the higher is the content of vitamin A. Dark green vegetables also contain iron and vitamin C. Fruits are the main source of vitamin C. Sweet juice is an alternative carbohydrate source.

Fish and meat – protein sources
Fish and meat are protein sources and important sources of vitamin B. Clear boiled soups of fish or meat may be used as a fluid base for the tube-feeding suspensions. Well-dried fish and meat are safely stored also in hot climate, and may be ground and used in tube diets. Ground dried fish including fish bones is a concentrate of calcium and trace elements. Some types of fish (sardines) are fatty; fish oil is a valuable source of energy and vitamins A and D.

Milk – a fluid base for tube diets
Milk contains protein, calcium and vitamins. Milk from camel, buffalo and sheep is especially rich in fat and is a source of energy. Fresh milk is easily contaminated. Soured and fermented milk has the same nutrient value, but it is easier to digest, and carries less risk of contamination – it should be used as the milk base. Soft or hard cheese made of milk keeps well in storage and is an important source of energy. Donated powder from whole milk or skimmed milk, and milk substitutes made from full-fat soy powder are alternative bases for tube-feeding suspensions.

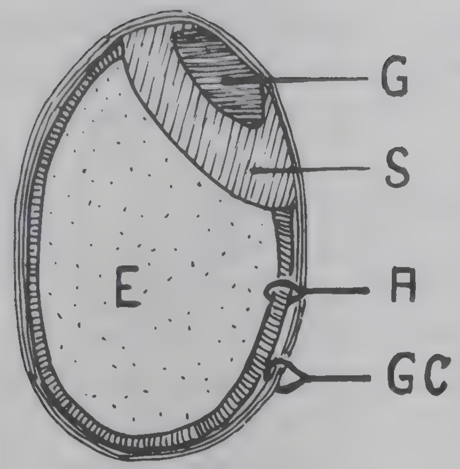
ilk contains lactose that contributes diarrhea in high-energy enteral be feeding. Some populations lack testinal enzymes necessary for the gestion of lactose.

, Faffa and Dubbe, donated soy- wder agents made in Egypt

Food processing and the viscosity problem

Use traditional methods
We recommend traditional methods for food processing and preservation:
- Experience has proved them safe
- They are cost-effective
- The local population may share in the production at your clinic

5



5 Milling of cereal grains removes the outer layers of the grain. Important vitamins and protein are lost in this process: The germ (G) and the scutellum (S) contain most of the protein and vitamin B which are lost when the aleurone layer (A) and the germ coat (GC) are removed during the milling process. The end-product is a flour of good digestibility, but of poor nutrient value. Rice grain is rarely milled into flour. But the grinding of rice represents no technical problem, rice flour is an important and well-digestible carbohydrate source.

Use lime water to soak maize before grinding: That increases the calcium content of maize flour.

Fermentation
In many areas there is a tradition to soak the grain in water before grinding. In a hot climate soaking starts a process of fermentation that breaks down the starch of the grain and reduces viscosity of the flour suspensions. There is a risk that soaking or damping the grain contaminates the flour: Diets made from flour after fermentation should be cooked well before use.

Parboiling
Parboiled rice and parboiled wheat ("bulgur wheat") store better than ordinary rice or wheat. The flour made from parboiled rice also has better nutrient values than plain rice flour.

Drying
Meat and fish are slightly salted before drying to prevent contamination. Dried vegetables may be ground and the powder stored.

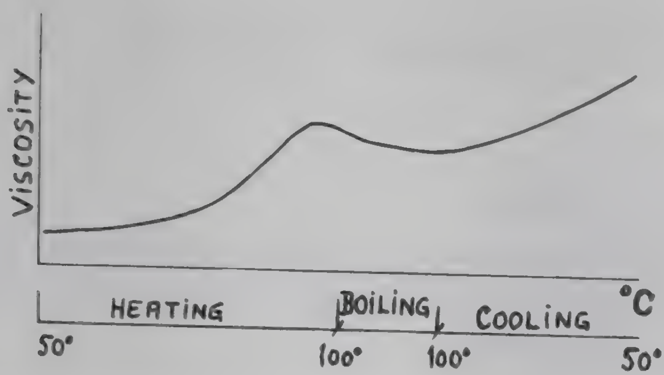
The viscosity problem

The problem: Cereal flour absorbs water during cooking. The high content of starch in the flour increases the viscosity of the suspension. When the suspension is set aside for cooling, the viscosity increases further.

The poor solution: You may reduce the viscosity of the feeding suspension by diluting it with water – but that also reduces the carbohydrate content.

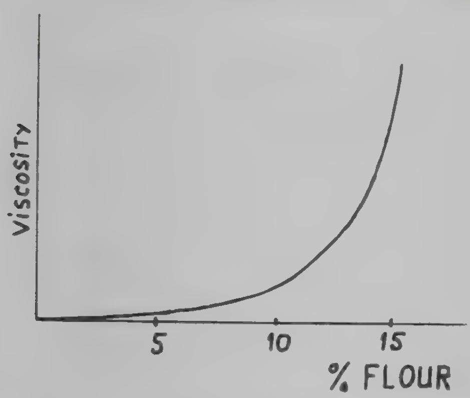
The good solution: Suspensions made of fermented flour mixed with sugar and fat have low viscosity – concentrated solutions can pass through the feeding tube; there is less risk of intestinal overload.

6



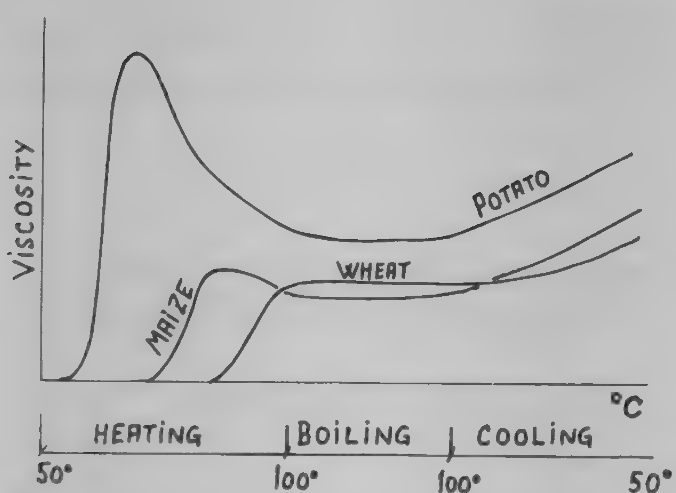
The viscosity problem: The viscosity of cereal flour-ater suspensions increases during cooking. The starch ranules swell when heated, and create a gel. The gelati-ization process continues when the boiled suspension is ooled.

7



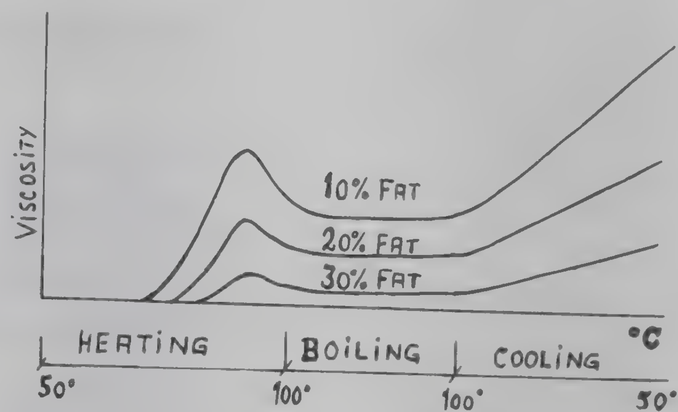
The viscosity increases with increasing concen-rations of flour.

8



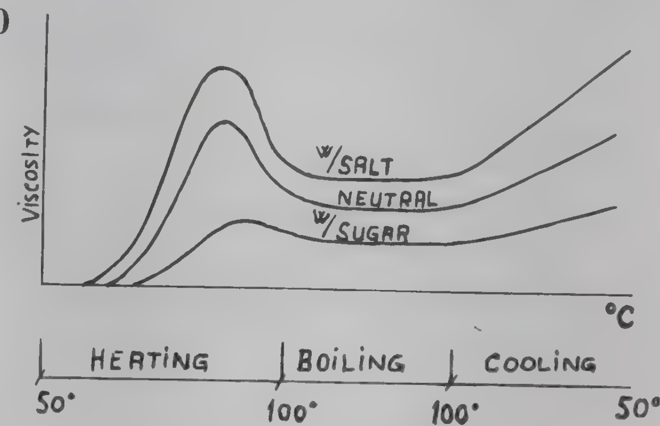
The degree of gelatinization differs with the rious types of cereal flour, but all flours containing arch follow the basic pattern.

9



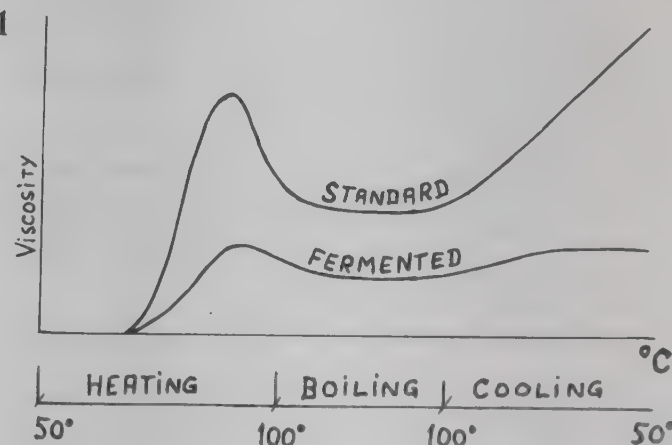
9 Fat reduces the viscosity of flour suspensions: Increasing amounts of fat added to the flour suspension reduce the viscosity correspondingly.

10



10 Sugar reduces, and salt increases the viscosity of flour suspensions: Sugar reduces the swelling of starch granules and the gelatinization during cooling. Salt added to cereal grain flour has the opposite effect.

11



11 The definitive solution to the viscosity problem is fermentation or malting of the cereal flour: The grain is soaked in water or dampened, then exposed to heat (in the sun or in a heater, 40-60 degr. C) for 6-24 hours to start the fermentation process, then dried and milled. The fermentation breaks the starch granule, and reduces the viscosity of the flour suspension without reducing its nutrient value. The reduction of viscosity is about 75% – the reduction is permanent and not affected by heating or cooling later on.

Home-made diets for enteral feeding

Standard diet 1:
milk, sugar and animal protein as base
Where milk, sugar and dried fish/dried meat are available, a simple and cheap suspension is made from these foodstuffs. From **Tables 9-12** you find the nutrient values for the actual foodstuffs per 100 g:

Milk (cow)	3 g protein,	65 kcal
Sugar	50 g glucose	200 kcal
Oil (ghee)		900 kcal
Fish/meat (dried)	50 g protein	270 kcal

A mixed diet well fit for tube feeding is cooked, cooled and filtered through a screen or clean cloth:

Nutrient	**protein (gram)**	**glucose (gram)**	**kcal**
500 ml milk (cow)	15	60	325
500 ml water			
50 g sugar		50	200
25 g oil/fat			225
30 g dried fish/meat	15		100
1000 ml contain	30	110	850
3000 ml contain	**90**	**330**	**2550**

Field standards of volume and weight: p. 625.

Add dark green vegetables, orange fruit and 4 g salt to each 1000 ml solution. Taste it: The solution should not be more saltish than your own tears. This diet corresponds to the energy demand of a moderately severe adult injury case. Add or reduce fat depending upon the calculated total energy requirement for each patient.

Standard diet 2:
cereal flour as carbohydrate base, vegetables as protein base
From **Tables 9-12** you find the nutrient values of the foodstuffs per 100 g:

Cereal flour	10 g protein	80 g glucose	350 kcal
Beans (dried and ground)	25 g protein		350 kcal
Oil (any oil)			900 kcal

Fermented flour is cooked with oil and salt, cooled, and the final suspension filtered through a screen or clean cloth.

Nutrient	protein (gram)	glucose (gram)	kcal
1000 ml water			
100 g flour	10	80	350
100 g beans(dried and ground)	25		350
30 g oil/fat			270
1000 ml contain	35	80	970
3000 ml contain	**105**	**240**	**2910**

Add dark green vegetables, orange fruit and 4 g salt/1000 ml. Taste the suspension. Compared to a milk-based diet, this suspension produces less vomiting and diarrhea. It is also more resistant to contamination. The diet fulfills the requirements of most post-operative adult cases. The content of fat should vary from patient to patient according to calculations done.

Table 9
The main protein sources (values per 100 g foodstuff)

	protein (gram)	kcal
Legumes in general (lentils, chickpea, kidney bean, mungo bean, soy bean etc.)	25	350
Eggs	15	150
Fish, raw	20	80
Fish, dried	50	270
Meat	20	150-250
Meat,dried	50	400-700
Milk – cow, goat, camel	3-4	70
Milk – buffalo, sheep	5	100
Soft cheese	15	100
Hard cheese	30	400
Yogurt	4	90
Milk powder	25	500

Table 10
The main carbohydrate sources (values per 100 g foodstuff)

	glucose (gram)	kcal
Sugar	100	400
Honey	75	300
Banana	25	115
Apple juice	30	120
Grape juice	30	120
Grapefruit juice	20	80
Orange juice	20	80

Table 11
The main energy sources (values per 100 g foodstuff)

	protein (gram)	kcal
Melon seeds	25	600
Sesame seeds	20	600
Butter		700
Ghee (butter oil)		900
Red palm oil		900
Vegetable oils		900

Table 12
Combined protein-energy sources (values per 100 g foodstuff)

	glucose (gram)	protein (gram)	fat (gram)	kcal
Flour – wheat, maize, rice	80	10		350
Soy bean, flour		35	20	400
Ground-nut, flour		25	45	600
Coconut	80			375
Coco milk	60	5		260
Melon/cotton seed		20		600
Bulgur wheat		11		350
Bulgur wheat (soy fortified)		17		350
Corn soy milk		20		380
Faffa (full-fat soy)	66	17		370
Dubbe	73	11		360
Whole milk powder	40	26		500
Skimmed milk powder	40	36		350

How to improvise from local foodstuffs

First: Estimate the nutritional requirement of your patient (70 kg)

- Glucose 3-4 g/kg/24 hours as a standard:
  That makes 200-300 g glucose/24 hours.
- Protein 1.3 g/kg/24 hours as a standard in cases of non-starving patients:
  That makes about 90 g/24 hours.
- Total energy requirements (to be on the safe side, 25% is added to the calculated requirements):
  Stress level 1: 2700 kcal/24 hours
  Stress level 2: 3100 kcal/24 hours
  Stress level 3: 4200 kcal/24 hours

The degree of injury determines the stress level: p. 603.

Then make the diet – example 1

An adult (70 kg) with a comminuted open leg fracture, with no signs of infection, is in a good general condition. As a stress level-2 case he needs

- About 3000 kcal/24 hours.

etabolism of 1 g fat makes about 9
al.

- About 250 g glucose/24 hours. That is 1000 kcal/24 hours obtained from glucose.
- About 100 g protein/24 hours. That is 400 kcal from protein.
- Fat: The rest of the energy needed (3000 – 1000 – 400) = 1600 kcal/24 hours should come from fat intake.
  That is (1600 ÷ 9) = approximately 180 g fat/24 hours.
- Fluid: about 3000 ml fluids/24 hours depending upon the circulatory state.
- Electrolytes, vitamins and trace elements.

A diet is composed of available foodstuffs – rice flour, ground beans, fruits and oil:

heck the nutrient values from Tables
12.

	protein (gram)	glucose (gram)	kcal
Rice flour, 100 g	10	80	350
Fruit juice, 75 ml		25	100
Ground beans, 100 g	25		350
Oil, 25 g			225
Water 1000 ml			
1000 ml contain	35	105	1025
3000 ml contain	**105**	**315**	**3075**

Additives: Table salt, ground whole dried fish, ground dark green vegetables.

Make the diet – example 2

An adult (70 kg) with abdominal injury and perforations of the large intestine, has fever 38.5 degr.C. You classify him as a stress level-3 case. He needs

- About 3400 kcal + 10% = 3750 kcal/24 hours
  (Add 7% for each degree C of fever.)
- About 300 g glucose/24 hours. That is 1200 kcal from glucose.
- About 100 g protein/24 hours. That is 400 kcal from protein.
- Fat: 2150 kcal/24 hours. That is about 240 g fat.
- Fluid: about 4000 ml/24 hours.
- Electrolytes, minerals and trace elements. Assume increased losses of sodium, chloride and potassium due to the abdominal injury.

A diet is made from available foodstuffs, for example, maize flour, whole milk powder, orange juice, ground beans and oil:

heck the nutrient values:
bles 9-12.

	protein (gram)	glucose (gram)	kcal
Maize flour, 50 g	5	40	175
Milk powder, 50 g	13	20	250
Orange juice, 100 ml		20	80
Ground beans, 50g		15	200
Oil, 25 g			225
Water 1000 ml			
1000 ml contain	33	80	930
4000 ml contain	**132**	**320**	**3720**

Additives: Table salt, ground dried fish or meat, ground dark green vegetables.

Common high-energy diets for oral feeding

Give exact prescriptions – also for oral feeding

The general advice – "eat well" – is of little use in post-operative nutrition. Collect one or two high-energy diets from the local cooking tradition. Give the clinic staff, patients and their relatives prescriptions for cooking, for volumes and frequency of the meals.

Central Africa

120 g bananas
30 roasted ground peas
10 g dried skimmed milk
Contents of 1000 ml: 2300 kcal

150 g yam (sweet potatoes)
5 g meat
5 g melon seeds
40 g spinach
10 g tomatoes
10 g onion
10 g red palm oil
10 g dried fish
Contents of 1000 ml: 1400 kcal

60 g cassava
35 g meat
10 g tomatoes
10 g onion
5 g red palm oil
Contents of 1000 ml: 1400 kcal

South East Asia

25 g wheat flour
20 g mung bean
40 g spinach leaves
25 g carrots
5 g ghee
50 g bananas
50 ml milk
Contents of 1000 ml: 1700 kcal

40 g rice
15 g cereal flour
30 g dark green vegetables
5 g oil
100 g milk
50 g bananas
Contents of 1000 ml: 1200 kcal

70 g rice
30 g fresh fish
20 g onion
5 g oil
5 g fish clear soup
5 g malt
Contents of 1000 ml: 1400 kcal

Latin America

40 g rice
30 g kidney bean
10 g oil
10 g soft cheese
Contents of 1000 ml: 1700 kcal

60 g maize dough
10 g fat
25 g avocado
5 g onion
10 g hard cheese
lemon and salad
Contents of 1000 ml: 1450 kcal

North Africa

150 g potatoes
40 g dark green vegetables
20 g bean flour
5 g oil
Contents of 1000 ml: 1000 kcal

40 g tef flour
20 g bean flour
30 g dark green vegetables
5 g oil
5 g sugar
Contents of 1000 ml: 1200 kcal

Field standards of volume and weight

Some field standards may be useful when you instruct the patients in home-processing of diets. The clinic kitchen should use scales for better accuracy.

1 teaspoon	2.5 ml
1 tablespoon	7-10 ml
1 teacup	100-150 ml

1 tablespoon contains:
15 g oil
15 g milk
15 g sugar
10 g cereal flour
12 g flour from legumes
10 g sesame seeds
9 g milk powder

Table 13
Weight-volume relation of common foodstuffs

Foodstuff	Volume (ml) × **factor** = Weight (gram)
Rice	0.9
Noodles	0.9
Cassava flour	0.75
Refined cereal flour	0.65
Whole grain flour	0.55
Large beans	0.75
Small beans	0.9
Lentils	0.9
Ground-nuts	0.75
Sesame seeds	0.65
Sugar	1
Oil	1
Milk, liquid	1
Milk powder	0.45

Examples:
150 ml sesame seeds × 0.65 = 97.5 g sesame seeds.
1000 ml ground-nuts ÷ 0.75 = 1330 g ground-nuts

Points to note – Chapter 43

Study all sections of this chapter: Both medical staff and the patient's family should be engaged in the rehabilitation of war casualties.

Specially train in drawing up rehabilitation programs for individual cases: p. 628.

43 Exercises and physical rehabilitation

Draw up a rehabilitation program

Rehabilitation: To restore the injured body functions to the level they had before the injury. **And** to restore the social function of the injured to the level before injury.

Surgeon's responsibility
Good surgical craftsmanship is also to guide the total process of rehabilitation. No problem is "too small" to be cared for: Contracted fingers after hand injury can make a mechanic lose his job. Lack of walking aids may sentence patients to a life in bed who might otherwise have led a normal life.

The objectives of early physical rehabilitation
- Reduce the risk of post-operative complications: Respiratory exercises in bed and early ambulation after surgery reduce the rate of post-operative pneumonia – a main risk factor regarding secondary organ failure.
- To regain the maximal function: For each major case, set up a program on the first post-operative day that includes passive and active exercises in bed. And a rough, yet detailed, timetable on how the ambulation should progress: when to walk with human support, when to start on crutches, when to walk 100 steps continuously, etc.

Where there is no physiotherapist...
An active and optimistic milieu that cares for and supports the rehabilitation is very important: Train the staff in the basics of physical rehabilitation. Instruct all – from paramedics and cooks to the patient's relatives – to watch, encourage and advice the patient's training.

The patient is the key factor
Without active participation of the patient, the best rehabilitation program will be unsuccessful. To mobilize the patient, three factors are important:
- **Information – the patient must know the program:** Draw up the rehabilitation program bed-side together with the patient. Explain to the patient the probable progress he will experience. Explain all the must's and must-not's: how much he can load a fracture, what kind of exercises he should avoid, which symptoms indicate complications – and which are normal responses to training.
- **Psychological support – the patient must be able to understand the program:** During the first few days after severe injuries, most patients are not able to respond rationally to instructions given. So manage them like children – with kind, but firm, care: Concentrate on respiratory support, ambulation and passive exercises done by assistants. When the psychological confusion recedes, share the rehabilitation plans with the patient. You may have to repeat information frequently. Patience and positive backing, not criticism, is essential. The earlier you can make the patient ambulate and do active exercises, the sooner will the psychological reactions normalize and make him able to participate actively in the program.

Mental reactions to injury and surgery: p. 586.

- **Analgesia – the patient must be able to perform the program:** Pain makes the patient give up: Post-injury depression and sleeplessness can spoil the rehabilitation program. Pain may also prevent the patient from doing specific exercises necessary for his rehabilitation. The rehabilitation program thus includes a program for analgesia: What is the basic analgesia in each case, and the analgesia necessary before/during the physical training. **Notice:** The pattern of pain may change during the rehabilitation, so revise the analgesia continuously.

The complete rehabilitation program

Analyze the problem
- Identify the main problem/injury that prevents restoration of normal function.
- Discuss how function lost can be compensated for.
- Identify factors that may interfere with the training program.

Plan
- Set up a long-term time schedule including secondary surgery.
- Split the long-term plan into periods: Discuss the details of training to be done in each period.
- Precautions to take regarding the training load.
- Plan the analgesia.

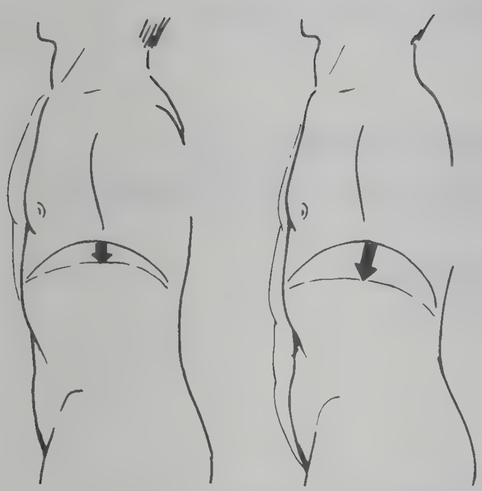
Implementation
- Inform the patient.
- Decide who are the clinic staff and family members responsible to assist and monitor the training.
- Revise the plan under way: Problems alway arise; discuss them with the surgeon responsible.

An example
- The problem: The patient had a proximal right forearm amputation and right eye enucleation done after a mine injury. He is a teacher by occupation. The below-elbow stump is too short to control a prosthesis. The primary aim of rehabilitation: To continue as teacher, he must transfer his right-arm function to the left arm. The secondary aim is to gain maximum function of the below-elbow stump so he can use it for dressing and daily duties. Factors interfering with the rehabilitation: He considers it impossible to continue teaching, saying "I can't even read."
- The planning: You plan secondary surgery within two months to improve the length and shape of the amputation stump. Until then: Concentrate on active and passive exercises of the right shoulder and elbow. There are no precautions regarding the training load. For mental support: Train him to write with the left hand, and order an eye prosthesis. For analgesia: Give pentazocine i.m. on demand, supplement with i.v. morphine before exercises, consider antidepressant as night dose. Two months after the secondary surgery he should be able to start teaching again.

Respiratory support and exercises

Objectives
- To inflate all lung segments, including the dependent ones
- To drain mucus from the airways

Measures
- Analgesia to promote deep respiration
- Get all patients out of bed on the first post-operative day, or at least they should sit/half-sit up in the bed
- Specific respiratory exercises
- Postural drainage

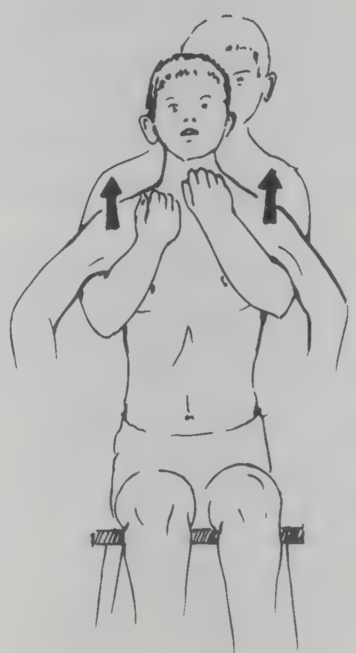
1


1 **Diaphragmatic breathing is better than thoracic:** Observe the motion of the chest and abdomen during breathing, and classify the type of breathing it is:
- Thoracic breathing: The muscles of the chest are the motor, the diaphragm hardly moves, the abdominal wall hardly rises during the inspiration. Thoracic breathing does not inflate the dependent lung segment; it increases the risk of atelectasis formation and pneumonia. Common reasons for thoracic breathing are pain, anxiety, or abdominal complications.
- Diaphragmatic breathing: The motor is the diaphragmatic muscle. You can see the abdominal wall rise during the inspiration. Diaphragmatic breathing inflates the dependent lung segments.

2


2 **Positive alveolar pressure:** Blowing surgeon's gloves each hour inflates the dependent lung segments and increases the vital capacity. This exercise is only effective when the analgesia is effective.

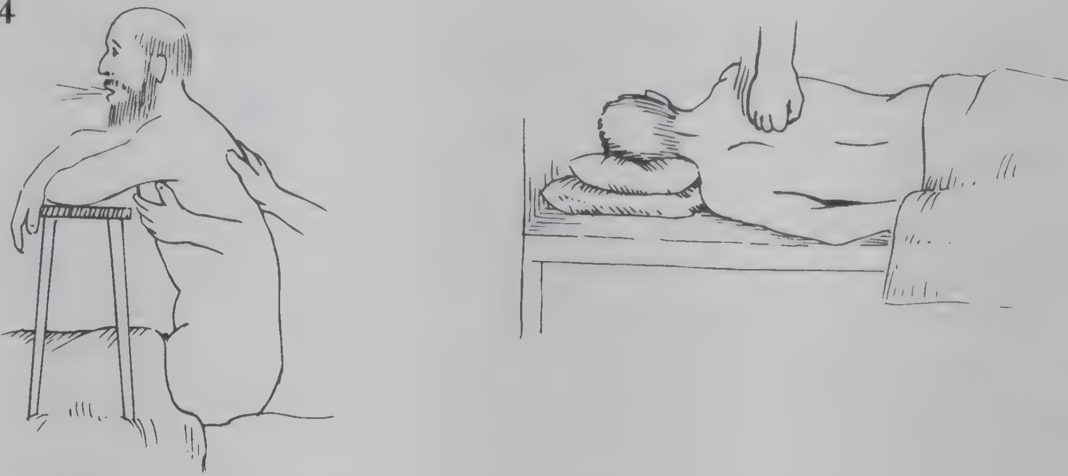
3

3 **Extend the chest:** Arrange a table or a transverse bar across his bed and tell the patient to breathe deeply. "Lift" the patient from the chair, instructing him to take deep breaths.

f rib fractures are the main cause of ain, give ketamine in analgesic oses, or morphine.

4



4 Chest drainage: Mucus may obstruct smaller bronchi and make lung segments collapse. Support the chest manually if the coughing is painful or ineffective. Postural drainage – here of the right lung: With one side down, beat the chest rapidly with your fist to make a low, frequent vibration that mobilizes the mucus. Tell the patient to cough at intervals while you support the chest.

Basic training therapy

Passive exercises: The motion is done without active contraction of the muscles.

- Why: The aim is to prevent stiffness and shortening of the joint capsule, ligaments, tendons and muscles.
- When: In the first post-operative period, passive exercises are the main part of the training program. When the patient gains in strength and motivation, active exercises become more important.
- How: The joints and muscles damaged or at risk of contracture are moved by the healthy parts – or by an assistant. The motions should be slow and not provoke pain.
- Rehabilitation of head and spinal cases: A comprehensive program of passive exercises is repeated frequently to prevent contractures.

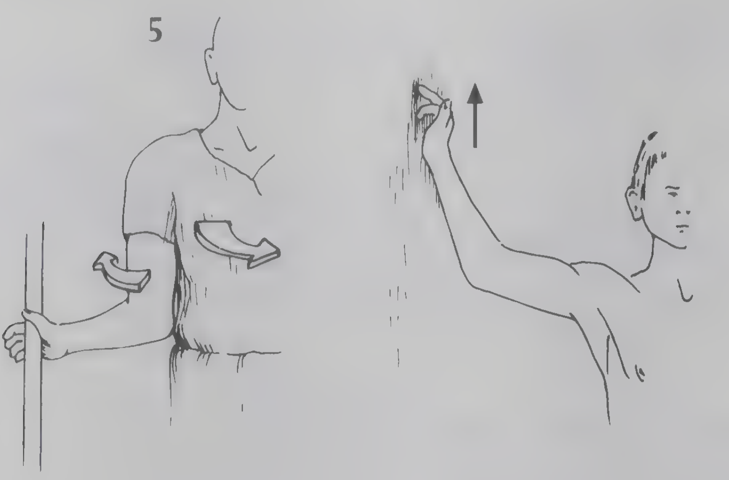
Active exercises: The motion is done by active contraction of the muscles.

- Why: The aim is to improve muscular force, sustainability and joint control.
- When: Early in the post-operative period active exercises are mainly a psychological measure. It helps the patient escape confusion and reorientate himself. When the patient enters the stage of reorientation, active exercises can be done effectively and should form the main part of the training program.
- How: Many repeated motions under low load are more effective than a few forceful motions.

Iental reactions after injury and surery: p. 586.

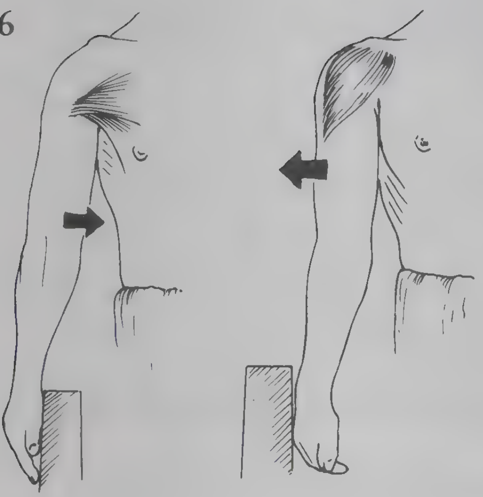
orrect load: He is able to repeat the iotion 15 times.

5



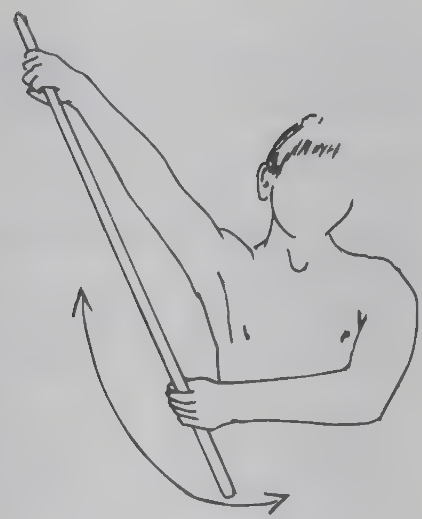
5 Passive exercises: Contractures at the shoulder joint primarily affect the anterior and lower parts of the joint capsule and muscle cuff (p. 486). Consequently the early passive exercises should especially train outwards rotation and abduction of the joint. That is done when, with the hand and forearm fixed, the forwards motion of the body causes outwards rotation at the joint. Running the fingers up the wall causes passive abduction at the joint.

6



6 Active exercises: Muscular control is important to stabilize joints after injury. Here the adduction and abduction strength is being trained.

7



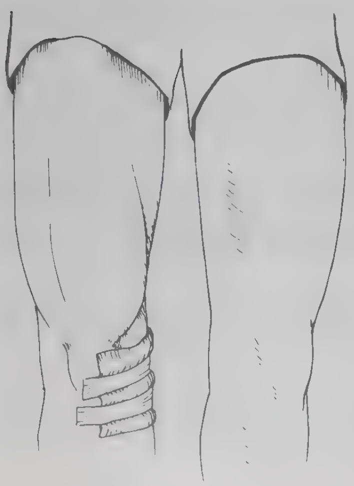
7 Combined active-passive exercises: In swinging the rod one way, the healthy left arm makes passive abduction at the injured right shoulder. The other way, the left arm loads the active adduction at the right shoulder.

"Isometric" = constant length
"Isotonic" = constant tension/force

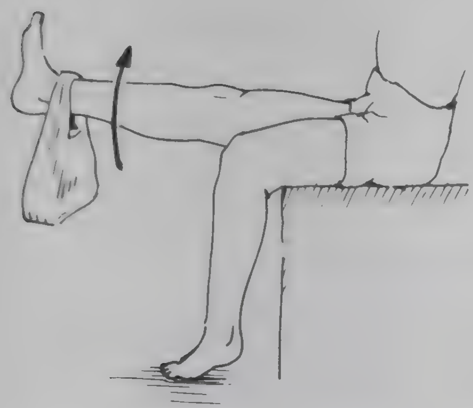
Two types of active exercises

- **Isometric exercise:** Opposing muscles at a joint contract, but the joint does not move. Isometric training should be done with immobilized limbs – inside plaster casts and under traction management of fractures. Isometric training helps prevent edema and should start on the first post-operative day. Isometric contraction can also be used to train the control of specific muscle groups.
- **Isotonic exercise:** One group of muscles contracts and moves the joint. The objective is to promote the joint motion and to increase muscular strength.

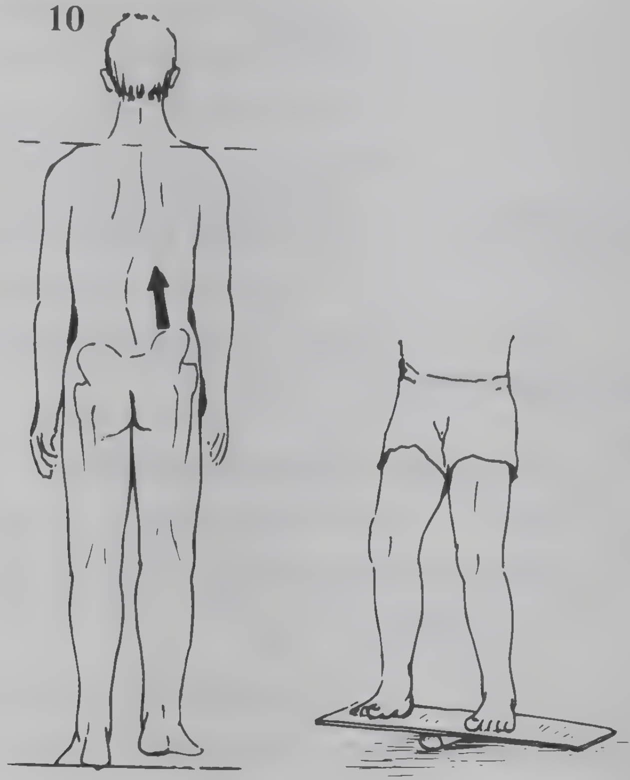
8



8 Isometric training: Control of the quadriceps muscle is essential to knee joint stability. Train the patient to do isometric contractions of the knee extensor (quadriceps) in bed from the first post-operative day. When the patient can control the contraction, start isotonic training.

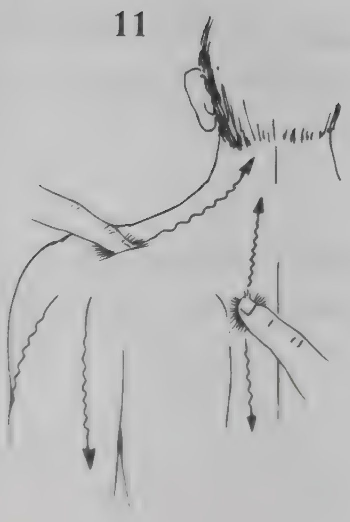
9


9 **Isotonic training** can increase/regain quadriceps strength. Let the patient monitor the diameter of the thigh week by week as a measure of muscle gain.

10


10 **Train the neuro-muscular control:** Long-term immobilization makes a patient "forget" how to stand and walk. Strength and control of the deep muscles at the pelvis and spine are partly lost. Also the function of balance becomes poor. Train the patient in tilting the pelvis and lower spine without tilting the trunk and the shoulder girdle. On the balance board the same muscle groups are being trained.

Soft tissue care
Edema and pain in muscles are normal responses to training. Excessive pain and edema indicate the training load may have been too high. Daily physiotherapy on the soft tissues may prevent secondary soft tissue reactions:
- Drainage therapy: transverse massage of the muscles and tendons stretches the tissues and stimulates the venous drainage.
- Trigger point therapy helps reduce the muscular pain and tension.
- Apply cold compresses to bruised soft tissues.

11


11 **Trigger point analgesia:** You can identify the trigger points by deep finger pressure: The pain radiates proximally or distally like "electricity". Temporarily block the trigger points by injecting local anesthetics (bupivacaine with adrenaline) exactly at the point of maximum tenderness; the injections should be repeated. Or reduce the trigger activity by continuous finger pressure on the point for 1-2 minutes.

Training after limb injury

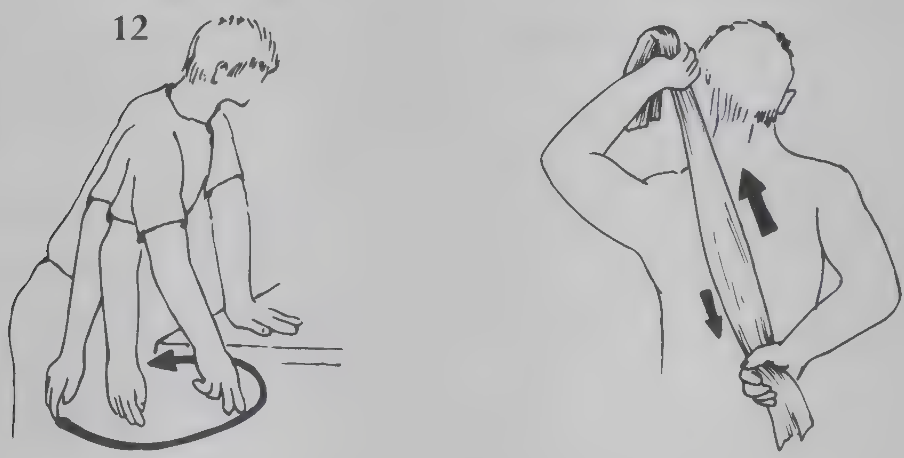
Dynamic and static traction: p. 212.

Illustrated patient instructions: p. 206.

Prevent contractures after immobilization
- Make the period of immobilization as short at possible.
- Apply dynamic instead of static traction whenever possible.
- Do not immobilize more joints than strictly necessary. Train the free joints of the injured limb during the period of immobilization.
- Train the parts immobilized with isometric exercises.
- Prevent edema complications inside the plaster cast: Split the primary casts. Give detailed instructions on preventive measures to all patients wearing casts.

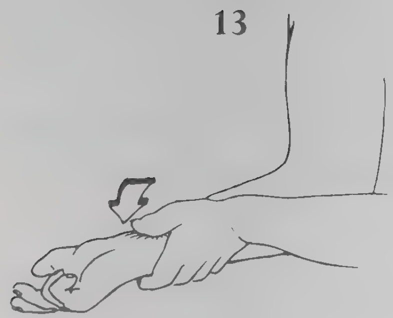
Training after immobilization
- Inform the patient that painless training is impossible: Mobilizing stiff joints normally causes swelling and pain at the joints.
- Warming the joints before training makes the training less painful and more effective.
- Consider analgesics before the training hours. Consider ice-packs and non-steroid anti-inflammatory drugs if the soft tissue reaction becomes grave.

12



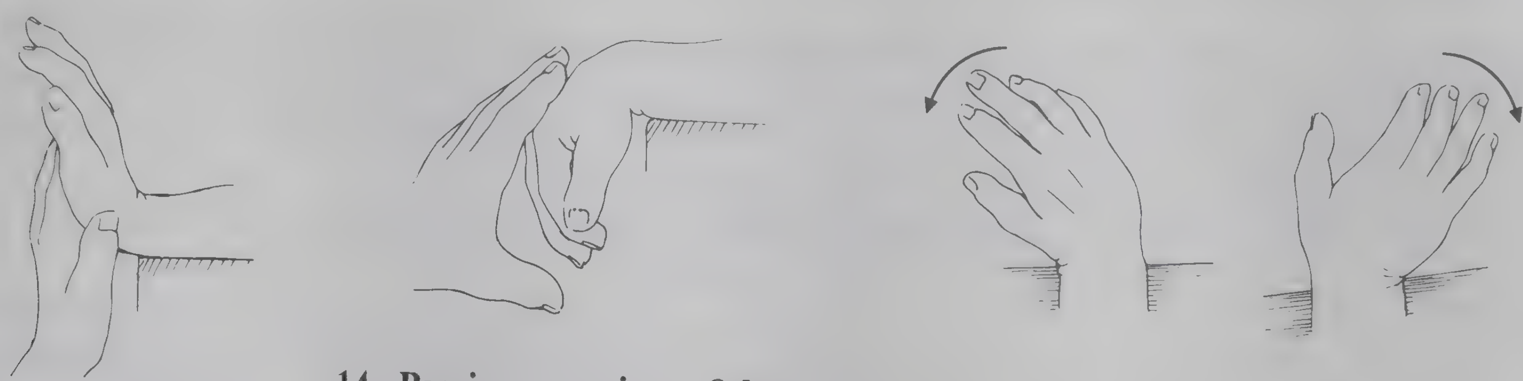
12 Exercises at the shoulder joint: Pendulum training starts immediately after surgery, also on arms wearing plaster casts. Concentrate the training on external/internal rotation and abduction (ill. 5).

13



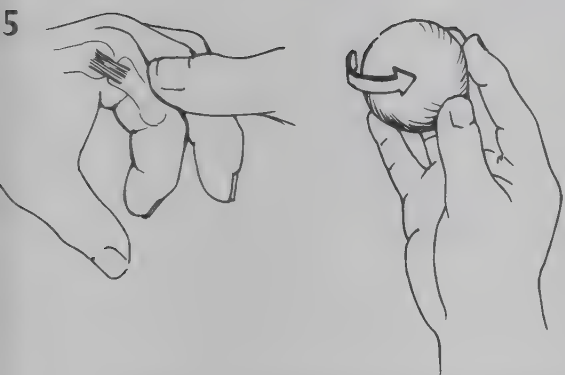
13 Specially train the supination/pronation of the forearm: It is essential to the function of the hand. Unless specific passive exercises are done, supination deficits will persist.

14



14 Passive exercises of the wrist: The training should include radial and ulnar deviation and forearm supination training.

5

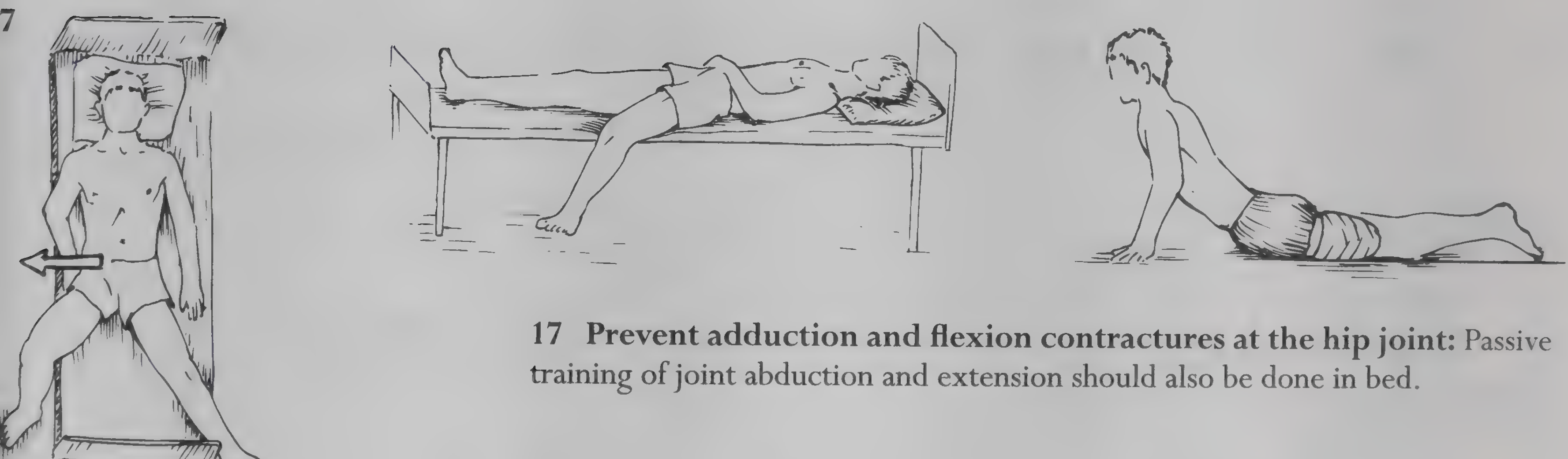


15 Train the small finger and carpal joints: Contractures first form at the MCP joints: Do passive exercises on each joint separately. Use the small soft ball to mobilize the carpal joints.

16

16 Lower limb training should include the pelvis and lower spine. Also see ill. 10.

7

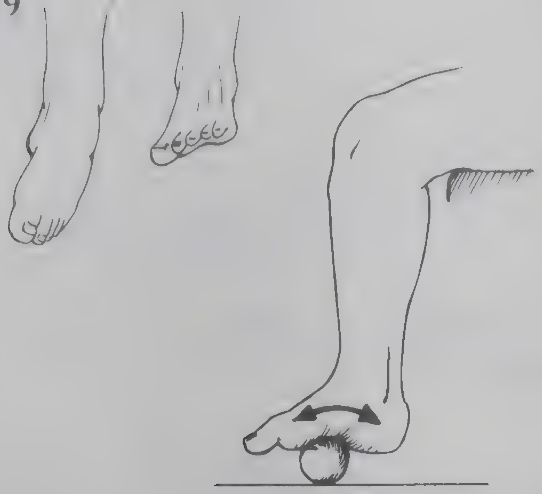


17 Prevent adduction and flexion contractures at the hip joint: Passive training of joint abduction and extension should also be done in bed.

18

18 Training the knee joint: Concentrate on quadriceps training and prevention of flexion contractures. The quadriceps training should start with isometric exercises on the first post-operative day (ill. 8). Then encourage elevation of the extended leg. Notice that normal motion of the knee includes an over-extension of 5-10 degrees which is essential to normal walking. Do passive exercises, press the joint towards over-extension to prevent extension deficits.

19

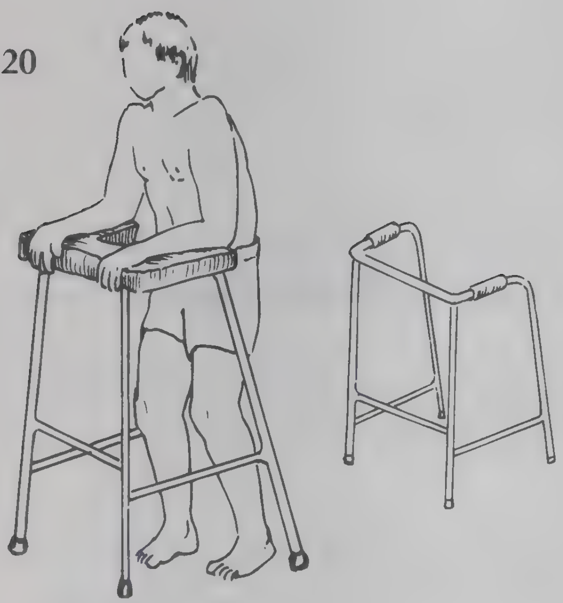


19 Training the ankle and foot includes the following:
- Isometric training of the lower leg prevents muscular waste and helps drain the foot: Contract all muscles of the limb for some seconds while keeping the joints in neutral position.
- Train passive and active flexion/extension and pronation/supination of both ankle and foot.
- Do specific exercises for supination of the foot: Supination is essential to normal walking, but is often lost after lower leg immobilization. Train control and strength of the peroneus group of muscles that elevate the lateral parts of the foot.
- Mobilize the small tarsal and toe joints: When done under some pressure, the ball massage moves the small joints of the foot.

Ambulation and walking aids

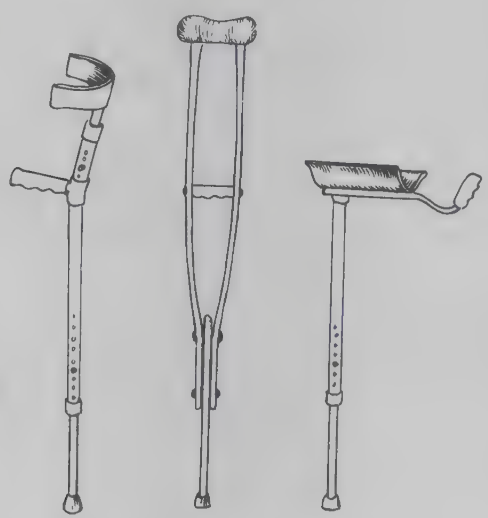
> Early ambulation is the best respiratory and antithrombotic therapy after surgery. Some simple aids make the training more effective; they can be made by any skilled carpenter/mechanic.

20



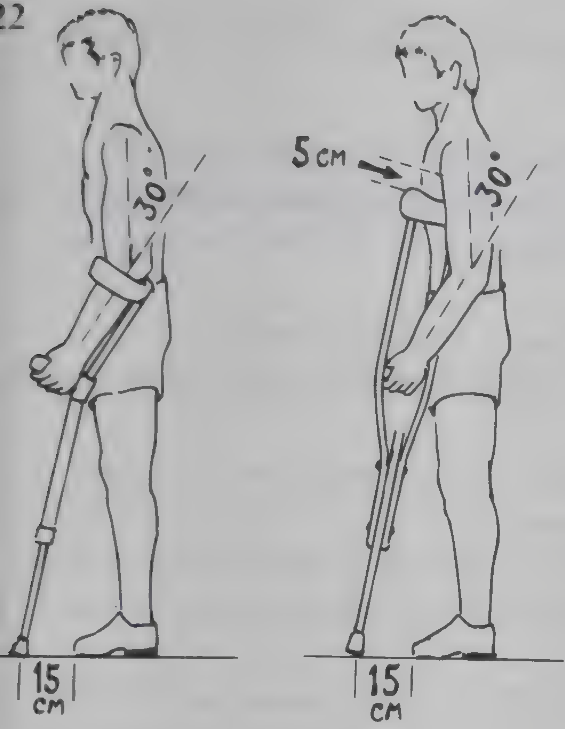
20 Walking aids: Let weak patients use the pulpit frame. The standard frame also trains upper limb strength.

21



21 Three main types of crutches
- The elbow crutches: These standard crutches also train the arm and forearm strength.
- The axillary crutches are used where the upper limb muscles are too weak to control the elbow crutches.
- The gutter crutches are used in cases with elbow or hand injuries.

22



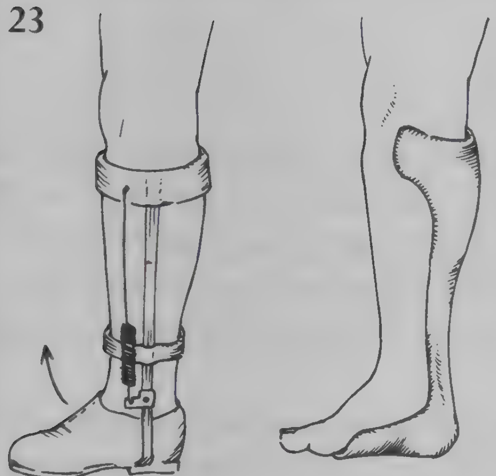
22 Adjust the crutches to correct length: Let the crutches reach the floor 15 cm in front of the patient, the elbows flexed at 30 degrees. In this position the length of the crutches should be so that the hand support is at wrist level (elbow crutches), and there is gap of three fingers between the axillary pad and the axillary fold (axillary crutches). **Notice:** Check that the shoulders are not hunched, and not depressed.

Crutch walking

There are serveral patterns of gait:

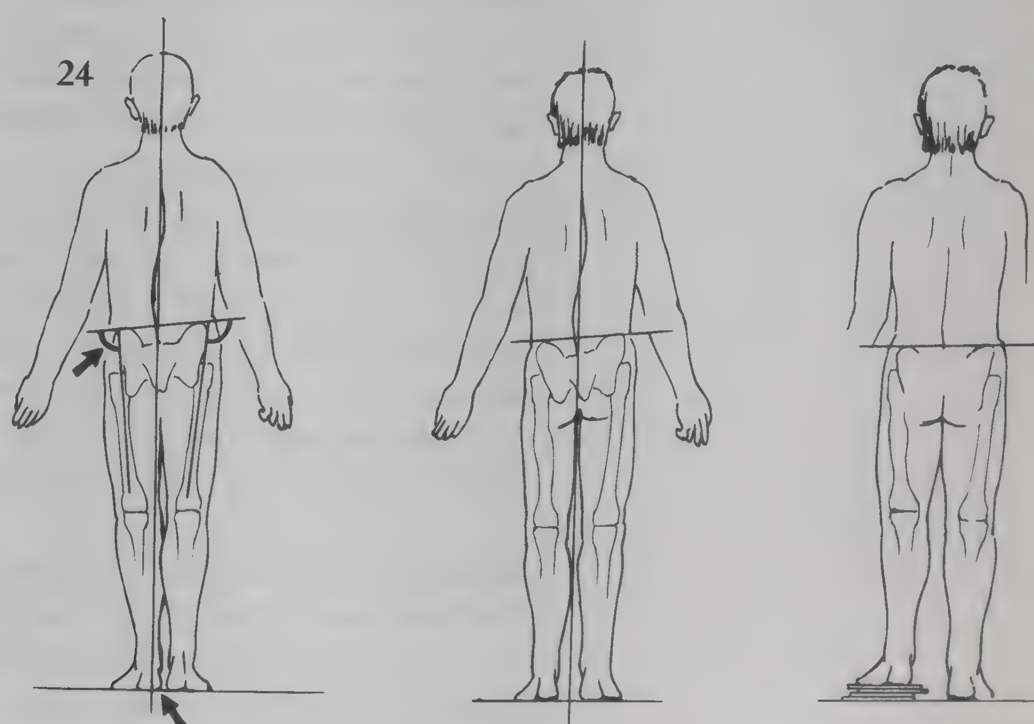
- Swinging gait: Both crutches are moved forwards in parallel. The body/legs are swung forwards to – or through – the crutches.
- Three-point gait: A swinging gait, but only the healthy leg takes the weight.
- Four-point and two-point gait: The opposite leg and crutch are moved – the right leg and the left crutch forwards, the left leg and the right crutch forwards. Two-point gait: The crutch and leg are moved simultaneously, the patient's balance must be good. Four-point gait: The crutch and leg are moved one by one making a wider base of support for unsteady patients.

23



23 Home-made toe-raising devices: After leg nerve injury or neurological disorders these simple devices prevent secondary joint damage and permit social rehabilitation. Supportive splints are made from polyethylene (orthoplast).

24



24 Leg inequality may cause secondary spinal problems

- First – check that the leg inequality is true and not only apparent: Fixed abduction deformity (arrows) or adduction deformity at the hip joint makes the patient tilt the pelvis and flex one knee. The legs seem unequal, but are in fact of equal length. The management is training to mobilize the hip joint.
- If one leg is shorter than the other by 15 mm or more (adults), heel-raising footwear is needed: Put wooden plates under the short leg until the spinal curvature is partly corrected, and the patient feels comfortable. That should be the height of the raise which is done inside or outside the footwear.

Rehabilitation after head and spinal injury

Common post-operative complications: p. 318.

Most complications in unconscious or paretic patients can be prevented:

- Increase the nursing capacity: Proper rehabilitation presents an immense loa on the clinic staff. Instruct the patient's family to do the basic nursing and training.
- Prevent aspiration: Use stable side position in comatose cases.
- Respiratory support: Let the patient sit or half-sit in bed, turn him at regula intervals.
- Bedsores: Use a soft mattress, alter position and massage the soft tissues frequently, especially on bony prominences.
- Contractures: Draw up a time schedule for frequent passive exercises of all joints which the patient cannot move. Use night-splints to support neutral position of joints at risk.
- Secondary surgery: Consider surgical mobilization of contracted joints for rehabilitation and nursing reasons (tenotomy, capsulotomy). Calcification in the soft tissues surrounding major joints is often seen in paretic patients. Surgical resection of bony patches may be done, but the calcification often redevelops.

Mental rehabilitation after head injury

- Six-month training program: Mental alterations after a major head injury car make nursing and rehabilitation difficult. In most cases it is possible to modif the mental response and behaviour by a mental-training program. Mental rehabilitation is a long-term process, and much patience is necessary: The maximum level of mental performance can only be reached after six months or more of mental training.
- Who will benefit from mental-training programs: Immediately after the head injury, there is usually a period during which the patient cannot remember anything. The longer this period of post-traumatic amnesia, the less chance o full mental recovery. Expect head cases with a period of post-traumatic amnesia of less than one week to have good mental recovery within one year of mental training. The depth of unconsciousness after the injury seems to be less important as a predictive factor. There are individual variations.

Guidelines for mental rehabilitation

- Profound mental disability – that is, patients without response to stimuli or with only weak response to pain stimuli: The rehabilitation consists of daily routines of systematic stimulation of all senses – hearing, vision, touch, smell etc.
- Moderate mental disability – that is, patients with varying degrees of agitation, aggression and confusion: The mental training concentrates on mental control. Demand that he controls his response to the environment; encourage him when he does so.
- Minor mental disability – that is, patients with some sort of "automatic" behaviour, patients with poor memory for recent events etc: The training concentrates on recall exercises, social communication and intensive physical training.

Rehabilitation of multi-injury patients

Planning rehabilitation: p. 628.

In the clinic
- Make a comprehensive physical training program together with the patient.
- Prevent physical complications during the early stages of the physical rehabilitation (contractures, bedsores etc.).
- Start the mental training.

Out-patient rehabilitation includes
- Vocational rehabilitation: Plan the future workplace. The aim is reasonable full-time duties also for the most mutilated patients.
- Recreation: Performing a long-term rehabilitation program is strenuous. Regular and scheduled breaks with recreation under comfortable conditions have proved to be a great stimulus for long-term rehabilitation cases.
- Adapt the environment to the patient's capacity:
  Minor modifications in his home and at the workplace can make his life "normal": modification of furniture and beds, toilet arrangements, doorway and stairs etc. Regarding simple improvisations, a skilled carpenter does a better job than most doctors.

The main limit to social rehabilitation of multi-injury patients is the mental motivation: Convince him he can do "the impossible".

Points to note – Chapter 44

Know some definitions

- what is infection: p. 643. The clinical signs: p. 580
- what is septicemia: p. 644. The clinical signs: p. 459
- what is septic shock: p. 645

Identify the bacteria responsible for the infection

- how to make a qualified guess: p. 649
- know the bacterial pattern of different types of infection: Use Table 2 on p. 649

Stop the irresponsible use of broad-spectrum antibiotics

- know the serious side effects of broad-spectrum antibiotics: p. 582 and 656
- know the guidelines of correct antibiotic therapy: p. 656
- know the correct use of prophylactic antibiotics: p. 644

Both technical and medical staff should know the essentials of disinfection and sterilization

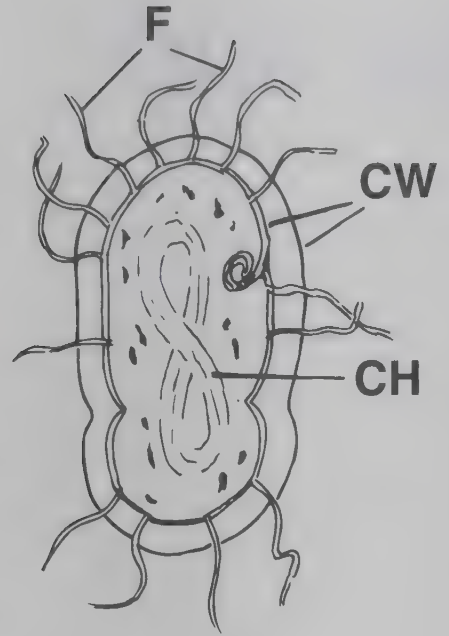
- study the whole section carefully: p. 69-70 and 656-659
- study the problem of hospital infections: p. 581

44 Microbiology and infections

What is bacteria

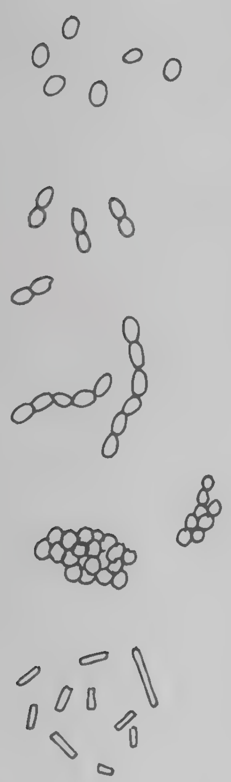
Bacteria are one-celled organisms. To survive and multiply, they need nutrition like other cells. Most bacteria manage that without harming other organisms, like the billions of bacteria that live in the soil. But the others, the medically important ones, "feed" on human tissues. For example, the enterobacteria are necessary for human digestion, but when they spread outside the intestine they are destructive. The dead and damaged muscles in war wounds are especially excellent food for disease-producing bacteria. Here they produce poisons – toxins or enzymes – which destroy the host tissues locally, and may injure vital organs when distributed by the bloodstream.

1



1 The bacterial cell consists of the cell wall (CW) which is different for each strain of bacteria; many bacteria also have a capsule outside the cell wall. All bacteria have cytoplasm and a nucleus which houses the chromosome (CH) with its specific genes. Some bacteria have many "tails" – flagella (F). Under difficult conditions, like the lack of food, or too much/too little oxygen, some bacteria (bacillus and clostridium) form spores. Spores are granules of genetic material housed in a thick capsule. Spores are tough and can survive hard conditions for long periods, sometimes years. Once conditions improve, the spores spring to action again, start to multiply, and produce enzymes and toxins.

2



Gram staining: p. 709

2 Classifying bacteria: Bacteria can only be seen with the help of the microscope. They can appear round (cocci), or like small rods (bacilli). These cocci and bacilli can be arranged in clusters, in chains, singly, or in pairs. With the simple Gram stain, they can either stain purple – gram-positive, or fail to stain, thus appearing pink – gram-negative. With Gram stain we can identify the type of bacteria in wounds and circulating in the bloodstream. We can thus predict their behaviour – a condition to control them.

Aerobic and anaerobic bacteria
Some bacteria die in the presence of oxygen: the strict anaerobes. Others need oxygen to live: the aerobes. Several bacteria can live both with and without oxygen. They thrive on dead tissues which have little or no oxygen, and cause spreading gangrene – they are often found in war wounds.

What is infection

Bacteria are everywhere: Throughout the human gut, skin, and various orifices like nose, ear and anus, bacteria live in large numbers, without causing damage.

This is why broad-spectrum antibiotics may cause systemic damage. Also see p. 656.

Bacteria are "friendly" most times: The bacilli in the intestines produce vitamins and help digest food. They protect the intestines from being invaded by other "unfriendly" and destructive bacteria.
Injury and surgery can make "friendly" bacteria become destructive: Let normal gut bacteria like E. coli from the colon multipy in the kidneys or

brain – and a most nasty infection results. Or let staphylococci, which the skin normally is full of, get a foothold in open fractures and hematomas – and you get the familiar osteomyelitis and abscesses.

The presence of bacteria does not equal infection

This is infection:

- when "alien" bacteria become established in a local organ or tissue
- when they multiply effectively
- and destroy tissue either locally
- or destroy remote organs through circulating toxin

Infection is a clinical – not a laboratory – diagnosis

A bacterial culture or the microscope may tell you which type of bacteria is responsible for the infection. But only you can decide whether there is an infection or not. And this you do by examining the patient

- locally for signs of wound infection
- and the overall state for signs of septicemia

igns of wound infection: p. 580.
igns of septicemia: p. 459.

Guidelines for treatment

Prevent infection

All wounds are contaminated with large numbers of bacteria. They multiply exponentially (by the power of two in each generation) in damaged tissues. Preventive measures:

- Wash bacteria from the wound: Remove dirt and clothes. Wash with large quantities of soap and boiled water to remove all visible contamination – anesthesia may be necessary.
- Remove what bacteria feed on: Excise all necrotic tissue as soon as possible after the injury. Wash out hematoma, drain to prevent hematoma from forming. As hydrogen peroxide removes blood clots effectively, wash with peroxide after debridement.
- Do not let other bacteria get to the patient or his wounds: Use aseptic surgical techniques, maintain good personal hygiene among staff, remove all dirty clothes, wash and scrub the operating field with large quantities of soap and water.

here is evidence that once there are 00 000 bacteria per gram of tissue, he infection is established.

Treat early infection

Most war wounds are very heavily contaminated, and wound infection is established 4 – 6 hours after the injury. Reduce the rate of wound infections and post-operative infections by

- a single massive dose of recommended antibiotics as prophylaxis as soon as possible after the injury
- radical excision of all necrotic tissue
- leave the wound wide open to prevent anaerobic infection

f the patient is not seen until 8-12 ours after the injury, the infection vould have been fully established by hen, and antibiotics should be given or days. See Table 3, p. 652.

Prophylactic therapy means
- high-dose antibiotics
- given for no more than 24 hours
- and only before and/or during surgery

Recommended routine prophylactic antibiotics (doses for adults, 50-70 kg)
- Superficial wound (not penetrating the muscle fascia): No antibiotics
- Deep injury (penetrating the muscle fascia): I.v. penicillin 8-12 mega IU as a single dose
- Penetrating chest injury: I.v. penicillin 8-12 mega IU or i.v. cephalothin 2 g as a single dose
- Penetrating abdominal injury: I.v. ampicillin 2-4 g and i.v. metronidazole 1.5 g as a single dose
- Penetrating skull injury: I.v. penicillin 8-12 mega IU or i.v. chloramphenicol 1.5 g

These are the basic antibiotics for wartime surgery. You can treat most cases without the more advanced and often expensive antibiotics listed in Table 3, p. 652.

Prolonged infection
- Look for a cause – do not simply give antibiotics: Has he got an abscess? Necrotic tissues left behind? A non-viable limb? Leaking intestinal anastomosis? An infected collapsed lung segment? Urinary tract infection? Or is he so weak that his body defences have simply given up?
- Remove the cause: Reoperate before the general condition further deteriorates.
- Support his defences: Help him breathe effectively. Support the blood circulation. Give high-energy nutrition.

A lesson from the recent history of wartime surgery: New generations of antibiotics have not prevented or reduced the rate of post-operative infections.

Persistent infection
Simply prolonging antibiotic treatment will just increase resistance to antibiotics.

Septicemia
The patient is ill, and his temperature chart shows typical septicemia fever. Early and aggressive intervention is essential:
- Most important, identify and control the source of the septicemia – where the circulating bacteria and/or toxins come from.
- Give high i.v. doses of two (or more) antibiotics based on a qualified guess: What is the probable bacteria causing septicemia? Take a blood culture if possible.

The temperature chart: p. 459.

Bacteria in common infections: Table 2, p. 649.

Septic shock

If the early management of septicemia fails, the probable result is septic shock. The mortality rate of final-stage septic shock is high. The clinical signs of septic shock are totally different from circulatory shock:

- The blood pressure is normal, pulse rate increased, extremities warm and dry during the first stages. During later stages of septic shock, the blood pressure falls and the heart fails, unless effective treatment is given.
- During early stages, the kidney function is normal. During later stages the kidneys, liver, intestines and coagulation system may fail.
- During early stages the temperature is increased, during late stages the endocrine system collapses and the temperature may fall to hypothermia.

The management of septic shock

- Most important: Identify, remove and drain the septic focus, even if the patient is weak. Consider surgery under local anesthesia in critically ill patients.
- Volume therapy: The patient is often hypovolemic due to the infection that caused the septic shock, peritonitis, burns, infected limbs. Rapid correction of the circulating volume is essential.
- Give large doses of two or more broad-spectrum antibiotics. Select antibiotics on a "qualified-guess basis" depending on what is the probable source of the septic shock.
- Monitor the circulation: Fall in BP indicates heart failure. Intermittent i.v. doses of ephedrine may have some effect. Normally digoxin has no effect on heart failure when there is septic shock.
- Monitor the urine production: Oliguria indicates hypovolemia or kidney failure.

Bacterial pattern in septicemia: p. 651.

Supportive cardiac treatment: p. 590.

Renal failure management: p. 591.

Bacteria important in surgery

Staphylococcus

Gram-positive cocci, arranged in clusters. Normally found on the skin, in the nose and throat of healthy people.

Yellow staphylococci may grow under anaerobic conditions.

- The yellow staphylococcus is common in wound and soft-tissue infections, osteomyelitis, septic arthritis, pneumonia and in septicemia. It produces several enzymes and toxins causing severe tissue breakdown. The typical staphylococcus abscess contains a thick yellow discharge. Most strains of yellow staphylococcus are now resistant to penicillin as they also produce the enzyme penicillinase that destroys penicillin. Thus different strains of yellow staphylococcus are important sources of hospital infections. If you suspect staphylococcus infection, penicillinase-stable penicillins (expensive) or first-generation cephalosporins (cheaper) should be the first-choice antibiotic.
- White staphylococcus is less harmful. It is a common cause of infected i.v.

Normally a growth of white staphylococci from a wound does not mean infection.

cannulas. White staphylococcus is often resistant to penicillin, also to penicillinase-stable penicillins.

Antibiotic sensitivity – yellow staphylococcus:
- 1st choice – cephalexin, cephalothin
- 2nd choice – methicillin, cloxacillin, dicloxacillin, flucloxacillin, clindamycin
- 3rd choice – methicillin, erythromycin, trimethoprim-sulfa, cephalosporins (1st and 2nd generation, do not use 3rd generation)

Streptococcus

Gram-positive bacteria arranged in pairs or chains.
- Streptococci (beta-hemolytic) produce a wide number of potent enzymes an toxins. They are potent and cause a variety of aggressive infections such as meningitis, infections after skull surgery, post-operative pneumonia, wound infections with cellulitis and necrotizing fasciitis, and post-operative septicemia. **Notice:** Streptococci are principally aerobic bacteria, but some strains grow better under anaerobic conditions. They may cause aggressive deep wound infection, often with cellulitis, and lung abscess.
- Pneumococci are paired cocci. They live in the upper airways. Important source of lobar pneumonia, upper airway infections, and meningitis.

Antibiotic sensitivity – streptococcus:
- 1st choice – penicillin
- 2nd choice – clindamycin (expensive, poor enterococcus effect)
- Penicillinase-stable antibiotics (eg. cloxacillin) cover both streptococci and staphylococci, but have poorer streptococcus effect than penicillin
- Tetracycline resistance is common

Enterococci

Gram-positive cocci of the family of streptococcus (Streptococcus faecalis). Living in the intestines, bile ducts and urinary tract, they may be a source of post-operative abdominal and pelvic infections. They grow under aerobic as well as anaerobic conditions.

Antibiotic sensitivity – enterococci:
- 1st choice – ampicillin
- Sensitive to penicillin G in very high doses
- Resistant to cephalosporins

Enterobacteria (coliforms)

A large group of gram-negative bacteria normally living in the intestine of man and animal. All strains have an exceptional ability to develop resistance to antibiotics and to transfer the resistance from one strain to another. Coliforms are

the most important source of abdominal infection after intestinal and urinary tract injury, often with abscess formation and septicemia. They are a common cause of hospital infections.

- Escherichia coli (E.coli) and klebsiella may cause peritonitis, abscesses and septicemia after abdominal and pelvic surgery, especially in clinics where much ampicillin is used. The infection may form gas.
- Proteus may cause infection after burns and in pressure sores.
- Enterobacter may cause abdominal infections and peritonitis. It is resistant to many antibiotics, and develops when heavy antibiotics have been used for some time.
- Salmonella is known as the cause of the epidemic salmonella enteritis, but may also form abscesses in muscles, arthritis and osteomyelitis.

Antibiotic sensitivity of enterobacteria cannot be predicted – these are the drugs of choice:
- Ampicillin – effective against proteus, but klebsiella and often E.coli are resistant
- Gentamycin and other aminoglycosides – 1st choice drugs against klebsiella and enterobacter
- Cephalosporins – but enterobacter may develop resistance
- Chloramphenicol
- Trimethoprim-sulfa – 2nd choice drug against klebsiella and proteus

Pseudomonas

It also belongs to the coliform group. It is normally found in the human intestines. Pseudomonas grows in moist climate, and may even proliferate in dilute antiseptic solutions. Being resistant to most common antibiotics, pseudomonas infections are often seen after irresponsible use of broad-spectrum antibiotics. Pseudomonas is a common cause of infections in weak patients, major burns, extensive soft tissue injuries, and in patients with indwelling bladder catheter. The smell of pseudomonas infections is often fruit-like (of strawberries) and the discharge is greenish.

Pseudomonas is an important source of hospital infections.

Antibiotic sensitivity – pseudomonas:
- Aminoglycosides (gentamycin, tobramycin) combined with piperacillin
- Colistin (neurotoxic, nephrotoxic)
- Ciprofloxacin (for adults only)
- Imipenem (expensive)
- Some 3rd-generation cephalosporins (ceftazidime, expensive)

Combine two antibiotics to prevent resistance from developing.

Bacteroides, fusobacteria and anaerobic cocci

This composite group of anaerobic bacteria all live in the colon and genital tract. They are important sources of abdominal and gynecological wound infections often combined with coliforms, and of anaerobic abscesses. The strain Bacteroides fragilis is especially a potent cause of abdominal and pelvis infections after injury; this strain is resistant to penicillin, even in high doses.

Antibiotic sensitivity – bacteroides and anaerobic cocci:
- 1st choice – metronidazole (all strains are sensitive)
- 2nd choice – chloramphenicol, trimethoprim-sulfa
- Clindamycin – Bacteroides fragilis may be resistant, most other strains are sensitive
- All strains are resistant to gentamycin and often to cephalosporins

Clostridium

This group contains gram-positive, sporing, anaerobic bacilli that live in the intestines, in soil and dirty water. They are a main source of anaerobic wartime infections. Clostridium tetani produces a potent neurotoxin that causes tetanus. Clostridium perfringens and other strains cause gas-producing aggressive infections in necrotic war wounds.

Antibiotic sensitivity – clostridium:
- 1st choice – penicillin G in very high doses
- 2nd choice – metronidazole, erythromycin
- Resistant to gentamycin and most cephalosporins

Clostridium infections are not managed by antibiotics alone – surgery is essential.

Haemophilus influenzae

The small, gram-negative coccoid rod lives in the upper airways. It is an important cause of pneumonia. In infants it also causes osteomyelitis and arthritis, often with septicemia.

Antibiotic sensitivity – Haemophilus influenzae:
- 1st choice – ampicillin
- Also sensitive to trimethoprim-sulfonamide, and cefuroxime

Common infections and common antibiotics

Several factors affect the actual bacterial pattern:
- Contamination from outside (soil and dirt)
- Unsterile surgical instruments can carry multi-resistant strains
- Indiscriminate use of broad-spectrum antibiotics may cause complex and uncommon infections

Base the drug therapy on a qualified best-guess
Work out the probable bacterial pattern in the actual infection. Base your guess on:
- the localization of injury
- local clinical signs – as color, smell, consistency and volume of pus. Wound signs as depth of the infection (anaerobic?), demarcation of the infection, cellulitis, abscess formation, local pain, gas formation
- general clinical signs – as general condition, septicemia, secondary abscess formation elsewhere in the body
- knowledge of hospital infections present
- knowledge of endemic infectious diseases of the area
- microscopic examination and Gram staining
- and the guidelines listed in Tables 1 and 2 below

Microscopic identification: p. 709.

Table 1
The normal bacterial flora

Skin	staphylococcus
	coliforms
Airways	staphylococcus
	streptococcus
	Haemophilus influenzae
Colon	enterobacteria
	enterococcus
	bacteroides
	anaerobic coccus
	Clostridium perfringens
	pseudomonas
Urinary tract	enterobacteria
	coliforms
	enterococcus

Table 2
Common bacterial patterns after injury and surgery – guidelines

Type of infection	Type of bacteria	Gram classification
Infection of skin and subcutaneous tissue		
Simple wound infection	staphylococcus	positive
Aggressive infections, cellulitis	staphylococcus	positive
	anaerobic streptococcus	positive
	streptococcus	positive
	pseudomonas	negative
	bacteroides	negative
	clostridia	positive

Type of infection	Type of bacteria	Gram classificatio
Abdominal inlet wounds and laparotomy incisions	E.coli	negative
	proteus	negative
	klebsiella	negative
	enterococcus	positive
	clostridia	positive
	bacteroides	negative
	yellow staphylococcus	positive
Infected burns	E.coli	negative
	beta-hemolytic streptococcus	positive
	pseudomonas	negative
Skin graft failure	beta-hemolytic streptococcus	positive
Infection of bone and joints		
Open fractures	yellow staphylococcus	positive
	streptococcus	positive
	enterobacteria	negative
	pseudomonas	negative
Osteomyelitis	yellow staphylococcus	positive
	pseudomonas	negative
	salmonella	negative
	Mycobacterium tuberculosis	positive, but poor staining
Brain infection	streptococcus (aerobes and anaerobes)	positive
	bacteroides	negative
	yellow staphylococcus	positive
Eye infection		
Superficial wounds	staphylococcus	positive
Penetrating injuries	pseudomonas	negative
	enterobacteria	negative
Abdominal and pelvic infection		
Peritonitis and intestinal injuries	normally mixed infection:	
	enterobacteria (seldom pseudomonas)	negative
	enterococcus	positive
	bacteroides	negative
	yellow staphylococcus	positive

Kidney and bladder injuries	normally mixed infection:	
	enterobacteria	negative
	pseudomonas	negative
	enterococcus	positive
Pelvic and vaginal injuries	bacteroides	negative
	streptococcus (aerobic and anaerobic)	positive
	pseudomonas	negative
Airway infection		
Post-operative pneumonia	Streptococcus pneumoniae	positive
	Haemophilus influenzae	negative
Aspiration pneumonia	yellow staphylococcus	positive
	bacteroides	negative
	anaerobic streptococcus	positive
Infected deep chest wounds		
Lung abscess	yellow staphylococcus	positive
	anaerobic streptococcus	positive
	anaerobic coccus	mixed
	bacteroides	negative
	klebsiella	negative
Septicemia: The bacterial strains depend on the source of infection		
Infected wounds, burns	yellow staphylococcus	positive
	streptococcus	positive
	pseudomonas	negative
	enterobacteria	negative
Infected fractures/bone	yellow staphylococcus	positive
	pseudomonas	negative
Abdominal infection	enterococcus	positive
	enterobacteria	negative
Urinary tract infection	enterobacteria	positive
Infected i.v. cannulas	white staphylococcus	positive
	enterobacteria	negative
	pseudomonas	negative
Multi-injury cases, weak patients, immune system failure	yellow staphylococcus	positive
	streptococcus	positive
	pseudomonas	negative
	enterobacteria	negative

Table 3
Common antibiotics and their action

Drug	Drug dosage adults (60-70 kg) Poor kidney function: Reduce the doses!	Cost of vials (cost of tablets may diffe
Penicillin G	i.v. 1-5 mega IU every 6 hours	moderate
Ampicillin	i.v. 0.5-2 g every 4 or 6 hours	cheap
Antistaphylococci (penicillinase-resistant penicillins)		
Cloxacillin	i.v 1-2 g every 4-6 hours	cheap
Dicloxacillin	i.v. 1-2 g every 4-6 hours	cheap
Flucloxacillin	i.v. 1-2 g every 4-6 hours	moderate
Methicillin	i.v. 1-2 g every 4 hours	moderate
Nafcillin	i.v. 1-2 g every 4 hours	moderate
Antipseudomonas penicillins		
Carbenicillin	i.v. 5 g every 4 hours (as infusion over 2 hours)	expensive
Piperacillin	i.v. 3-5 g every 4-6 hours (as infusion over 30 minutes)	very expensive
First-generation cephalosporins		
Cephalothin	i.v. 1-2 g every 4-6 hours	moderate
Second-generation cephalosporins		
Cefoxitin	i.v 1-2 g every 4-8 hours	expensive
Cefuroxime	i.v. 0.75-1.0 g every 6 hours	expensive
Third-generation cephalosporins		
Cefotaxime	i.v. 1-2 g every 6-8 hours	expensive
Ceftazidime	i.v. 1-2 g every 8-12 hours	very expensive
Ceftriaxone	i.v. 1 g every 24 hours	very expensive
Trimethoprim-sulfonamides	i.v. 100-200 mg (trimethoprim) every 6 hours	expensive

Antibacterial spectrum	Principal use
Gram-positive bacteria Most anaerobic bacteria Not Bacteroides fragilis	Limb infections Streptococcal and pneumococcal infections Clostridial infections Skull infections Preventive routine (not abdominal and pelvic injuries)
Better activity against gram-negative bacteria than penicillin. Better against Haemophilus influenzae and most coliforms except Klebsiella. Poor effect against anaerobes	Abdominal and pelvic infections Airway infections Systemic infections (combined with other drugs) Preventive routine (drugs of choice against enterococcus)
	Staphylococcal infection Osteomyelitis, arthritis
	Combine two antibiotics, consider aminoglycosides, ceftazidime, imipenem
Poor tissue penetration, good staphylococcal effect	Staphylococal infection Preventive routine
Good effect against anaerobes and intestinal gram-negatives. Less active against gram-positive cocci. Less staphylococcal effect than 1st generation. No effect against enterococci	
Effective against a broader spectrum of gram-negatives. No staphylococcal effect. Variable effect against pseudomonas and Bacteroides fragilis. Resistance develops rapidly	
Gram-positive and some gram-negative bacteria. Resistance to sulfonamides develops rapidly, thus sulfonamides should be combined with trimethoprim	Urinary tract infections Infections inside the skull Liver abscess

Drug	Drug dosage adults (60-70 kg) Poor kidney function: Reduce the doses!	Cost of vials (cost of tablets may diffe
Aminoglycosides		
Gentamycin	i.v. 120-280 mg every 8 hours	moderate
Tobramycin	i.v. 120-280 mg every 8 hours	expensive
Netilmycin	i.v. 160-320 mg every 8 hours	expensive
Tetracyclines		
Doxycycline	i.v. 100 mg every 12-24 hours	very expensive
Oxytetracycline	i.v. 0.5-1 g every 12 hours	very expensive
Metronidazole	i.v. 500 mg every 6-8 hours (as infusion over 20 minutes)	very expensive
Erythromycin	i.v. 0.5-1 g every 6 hours	very expensive
Clindamycin	i.v. 300-900 mg every 6 hours	expensive
Lincomycin	i.v. 600 mg every 8 hours	moderate
Vancomycin	i.v. 1 g every 12 hours	expensive
Chloramphenicol	i.v. 750 mg every 6 hours	moderate
Carbapenems		
Imipenem	i.v 0.5-1 g every 6 hours (as infusion over 30 minutes)	very expensive
Aztreonam	i.v. 1-2 g every 6-12 hours	expensive
Ciprofloxacin	i.v. 200-400 mg every 12 hours	very expensive

ntibacterial spectrum	Principal use
ctive against coliforms, pseudomonas and aphylococcus. Note: nephrotoxic and eurotoxic in doses close to the therapeutic level	Serious systemic gram-negative infection Urinary tract infection Combined with other antibiotics in staphylococcal infection Infected burns
Vide antibacterial spectrum, gram-positive d gram-negative. Proteus and pseudomonas e resistant	As resistance develops rapidly, tetracyclines are not drugs of choice in serious infections Can be used as preventive routine For patients older than 12 years only
naerobic bacteria including cocci, bacteroides d clostridia. No effect on aerobic bacteria	All anaerobic infections Abdominal sepsis Deep wound infection Necrotizing fasciitis Preventive routine
s penicillin, but less effective on anaerobes. aphylococcus may rapidly become resistant	Alternative to penicillin in pneumococcal and streptococcal infections in patients allergic to penicillin
aphylococcus, streptococcus, clostridium, ost anaerobes	Serious infections Staphylococcal infections where penicillins (also methicillin) and cephalosporins have no effect Anaerobic infections Necrotizing fasciitis, combined with metronidazole or a third-generation cephalosporin
road spectrum, but the effect against am-negative rods may vary. Often effective ainst clostridia and bacteroides. o effect against pseudomonas	Local application for eye injuries Serious systemic infections Infections inside the skull Salmonella infections
Vide antibacterial action. Resistance may develop pidly. Some strains of yellow staphylococcus, reptococcus and pseudomonas are resistant	Second-choice antibiotic in serious infections and septicemia where other antibiotics are not effective
fective against many gram-negative aerobes. No fect against gram-positives and anaerobes	
Vide antibacterial action. Effective against most terobacteria, several strains of staphylococcus d pseudomonas. No effect on pneumococcus. oor effect on anaerobes	Second-choice antibiotic in serious infections where other antibiotics are not effective Osteomyelitis with gram-negative rods Necrotizing soft tissue infections

Resistance to antibiotics

Potent antibiotics used for preventive measures, broad-spectrum antibiotics used on **unqualified-**guess basis, irregular administration, too low drug dose – all produce drug-resistant strains of bacteria: Initially sensitive bacteria become resistant to antibiotics. This can happen in three ways:

- The antibiotic fails to bind at the normal target site at the bacterial cell wall
- The bacterial membranes change permeability and cannot be penetrated by the antibiotic.
- Bacteria may start producing enzymes that inactivate the antibiotic agent.

Multi-resistance
Bacteria may develop resistance to more than one antibiotic – they become multi-resistant. Resistance and multi-resistance to antibiotics can be transferred from one bacterium to another.

Stop the irresponsible use of antibiotics
The more you use broad-spectrum antibiotics in a clinic, the more difficult strains will cause the hospital infections.

Correct antibiotic treatment reduces the risk of drug resistanc

- **Are antibiotics really necessary?** Antibiotics cannot penetrate an abscess or necrotic tissue – perhaps the patient needs surgery, not antibiotics. In mo cases he needs both.
- **Are broad-spectrum antibiotics really necessary?** The best bacteriological diagnosis is given by microscopy or culture. Without laboratory facilities, choose the drugs based on qualified guess. There are no standards to follow; each case must be assessed separately.

Specially in pseudomonas infections.

- **Combine two or more antibiotics in serious infections.** That may prevent drug resistance and increase the effect of both drugs.
- **Give the drugs in adequate doses:** Partly resistant bacteria may survive low doses (and even develop resistance), a few high doses will kill them.

Renal failure may increase the serum drug level and cause toxic reactions.

- **Give the drug in correct time:** Uncomplicated infections: 1-2 weeks. Prolonged infections: up to 6 weeks. Osteomyelitis: 3-6 months.
- **Use intravenous antibiotics in all seriously ill patients:** In bleeding injuries drugs are not absorbed after i.m. injections, the muscular blood flow is too low. Drugs are hardly absorbed from the intestines in weak patients, afte abdominal injury, and under circulatory shock.

Disinfection and sterilization

Hospital infections: p. 581.

- **Disinfection does not mean** destruction of all bacteria and spores.
- **Disinfection of an article means** reduction of the number of bacteria, thus making that article safe from the risk of transmitting infections.

Disinfection and wound care: p. 587.

Disinfectants are solutions capable of killing bacteria, but not spores. The effect depends on concentration and the time of action.

We recommend the use of soap-water solution as the standard disinfectant in wartime surgery and wound management. Compared to commercial disinfectants soap is available everywhere; it is cheap, free of toxic side effects and with a disinfecting capacity good enough for our needs. **Notice:** Mix dilute soap solutions (and other disinfectant solutions) every 24 hours, store cool – bacteria may grow in dilute solutions kept ready, but not in concentrated solutions.

Table 4
Some commercially available disinfectants

Dettol:	Wide-range antibacterial action. Irritant to the skin
Gammophen soap:	Gram-positive action
Diversol, Eusol:	Wide-range antibacterial action. Corrosive to surgical instruments
Betadine:	Wide-range antibacterial action. Hypersensitivity to iodine may be a problem for patients and staff
Formaldehyde:	Wide-range antibacterial action. Irritant to the eyes and airways
Cetavlon, Savlon:	Gram-positive action. Inactivated by soap
Alcohol (70%):	Wide-range antibacterial action, poor effect on spores
Chlorhexidine, Hibitane:	Gram-positive action. Hypersensitivity may be a problem

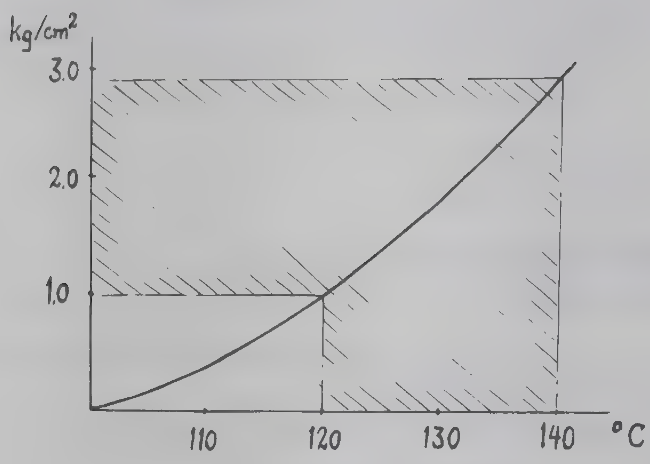
Heat as disinfectant
Heat is more effective as a disinfectant than chemicals: At 80 degr.C most bacteria (but not their spores) are destroyed within a few minutes. Washing instruments in soap solution and boiling for some minutes in water is an effective routine for disinfection. Washing-machines for surgical instruments should work at 85 degr.C.

Cleaning and maintenance of instruments: p. 69 and 70.

Practical routines
- Do not let debris and dirt dry before disinfection – wash instruments in cold water immediately after use, then disinfect them.
- The disinfectant must work over some time – no disinfectant is effective within seconds of action.
- Washing with soap and boiling for 20 minutes is the best method of disinfection.

Sterilization

Sterilization implies complete destruction of all bacteria and spores. There are several methods for sterilization: moist heat, dry heat, formaldehyde vapor, gaseous sterilization and gamma irradiation. For our use, moist heat is the method of choice.

3


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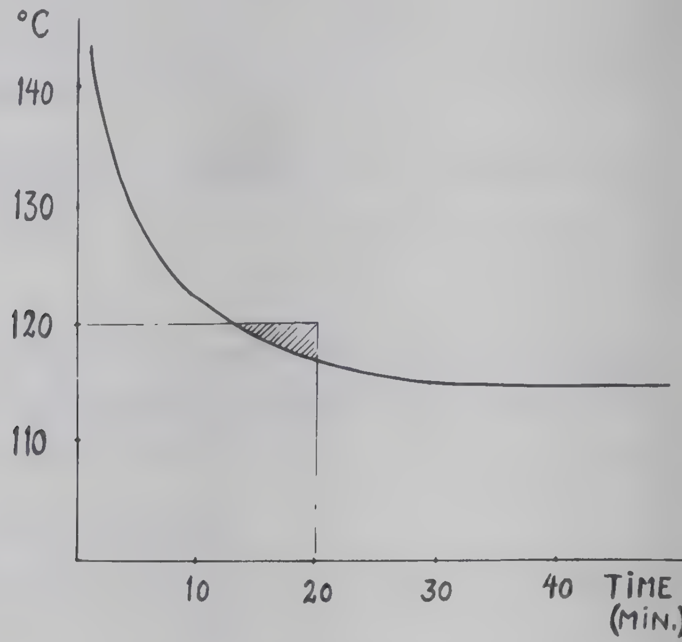
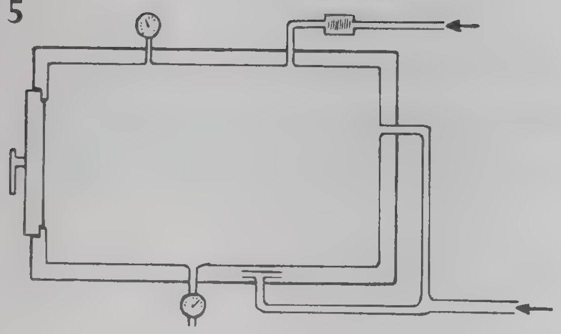
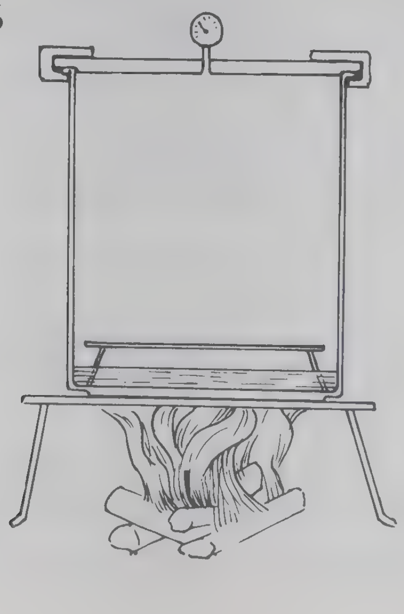


3 Sterilization by moist heat – pressure boiling: Under pressure, steam will increase its temperature with increasing steam pressure. The figure shows the relationship between steam pressure and steam temperature. The common range of sterilization is 120-140 degr.C, that is, between 1.0 and 2.7 kg/cm² (above 15 lb per in²).

4 TDT in relation to steam temperature: The time needed to destroy completely all bacterial spores is called Thermal Death Time (TDT). The TDT depends upon the steam temperature: The figure shows that all spores are destroyed by 120 degr.C within 15 minutes, or by 115 degr.C within 40 minutes.

5


5 The autoclave: Note the separate double steam inlet to the jacket and chamber and a separate air inlet with filter. The thermometer is located at the bottom of the autoclave, the pressure gauge at the top.

6


6 The pressure boiler: The instruments are lifted above water upon a grid. This pressure boiler does not have a thermometer, the temperature must thus be calculated from the pressure gauge. Add some time to the TDT due to the dry air content inside the pressure boiler (see text below).

Chemical and biological indicators are commercially available which may control the effect of the sterilization program.

Several factors affect the sterilization

- Air inside the pressure boiler reduces the temperature of the steam: In autoclaves air may be let out from the bottom of the autoclave (air being heavier than steam), that cannot be done in the pressure boiler. When sterilization by pressure boiling is used, steam pressure must be increased and at least 30 minutes added to the TDT to ensure a safe sterilization. If instruments or cloth packs are kept in metal boxes, the boxes must have multiple holes in the bottom to let the dry air "run out" of the box.
- The articles for sterilization must be clean: Dirt or oil film on the instruments will prevent the steam from penetrating to every bacterium or spore. Surgical instruments should not be closed.
- The pressure boiler and autoclave must not be heavily packed: The steam must be able to circulate and penetrate every pocket. This is particularly important when cloth packs are sterilized.
- Drying is done by letting the steam out of the chamber while the steam still circulates inside the jacket. The pressure boiler is unlocked to let the packs dry by evaporation. Handling of moist cloth packs causes contamination.

Pressure boiling at 120 degr.C for 15 minutes is a good standard for sterilization of surgical instruments.

Bacteria have different resistance to sterilization

- Least resistance: staphylococcus, streptococcus, E. coli
- Moderate resistance: Mycobacterium tuberculosis and related
- Most resistance: spores formed by clostridium strains and bacillus species.

"Sterilization" in a field setting

If an autoclave or pressure boiler is not available, a thorough disinfection is done by double boiling: Wash instruments in soap, rinse well, and boil them for 30-40 minutes. Let the instruments cool, and boil another 30-40 minutes.

Section 6
Field anesthesia

Points to note – Chapter 45

Study the whole chapter carefully – know the maximum doses and sid effects of local anesthetics: p. 668

45 Wartime anesthesia complications

The field anesthesia procedures:
- Local anesthesia
- Spinal anesthesia
- Ketamine anesthesia

What field anesthesia procedures have in common
- The practical procedures are simple.
- The technical equipment is inexpensive.
- The equipment necessary is small in volume and weight.
- The methods are fairly safe as long as basic precautions are followed.
- The procedures provide effective anesthesia for all kinds of surgery.

In extensive injuries, the key to success is combination of two or more anesthesia methods:
Eg. limb surgery under nerve block anesthesia combined with local infiltration anesthesia and/or low-dose ketamine analgesia. Or abdominal surgery under spinal anesthesia combined with costal nerve block and/or ketamine anesthesia.

Major stationary clinics
They should develop more advanced service in anesthesia:
- Ether inhalation general anesthesia (EMO apparatus) is simple, inexpensive and safe.
- Epidural anesthesia is useful in expert hands.

Airway obstruction

Aspiration

Basic life support: p. 129.

Patients for wartime primary surgery usually have full stomachs. There is a general high risk of vomiting with aspiration of gastric content into the airways. Aspiration to the airways is a serious complication: It may cause respiratory failure at the time of anesthesia – and it increases the risk of secondary organ complications.
Cases at risk of vomiting:
- Patients undergoing rough off-road evacuations
- Poor analgesia: Pain stimulates vomiting
- Morphine-type analgesics increase the risk of vomiting
- Abdominal injuries: Retention of fluid and gas in the stomach
- Patients in circulatory shock
- Hypotension during anesthesia: Spinal anesthesia on hypovolemic patients
- Head injuries

Risk cases due to poor swallow reflex:
- General weakness due to extensive injuries and evacuations
- Patients in circulatory shock

- Head injuries
- Hypothermic patients
- Drowsiness due to analgesics and tranquilizers given during evacuation and anesthesia

Ways to prevent aspiration

- Gastric aspiration (empty the stomach with gastric tube and suction) in non-urgent cases
- Suction apparatus and suction tubes at hand during all anesthesia procedures
- Emergency management: Know the procedure for applying cricoid pressure
- Be prepared to do endotracheal intubation at any time during any anesthesia procedure
- I.v. metoclopramide and atropine as premedication reduce the risk of vomiting and aspiration, but only to some extent. **Notice:** Give metoclopramide as premedication before you give the atropine, as otherwise it has no effect
- Morphine may cause vomiting in abdominal cases – low-dose ketamine analgesia is safer

Metoclopramide – doses and side effects: p. 151.

Free airway procedures

In any weak patient the tongue may block the airways, in particular, during analgesia and anesthesia.

These are musts for the anesthesia technician:

- He must know the head-tilt and jaw-thrust procedure
- He must be familiar with emergency ventilation for children and adults
- He must have and know how to use the oral airways
- He must be good at assisted SIB ventilation

Airway and respiratory management in detail: p. 135-143.

Circulatory collapse

The normal response of the sympathetic nervous system: Injury and pain cause

- shunting of blood from the skin and muscles into the central organ circulation
- increased heart rate and
- increased blood pressure

Spinal anesthesia blocks the sympathetic response to injury, and causes

- increased blood circulation in muscles and skin
- rapid fall in blood pressure

The physiological response to injury: p. 96.

The common mistake – a case study

One patient is admitted with a lower limb mine amputation. As analgesia given during the evacuation was poor, he is in much pain. His primary blood loss was 1500 ml; he got no volume therapy during the evacuation. But he arrives in a seemingly stable circulatory state: no bleeding, blood pressure 100 and pulse rate 130. His skin is cool and clammy, which you reckon is due to pain. With-

Degrees of circulatory shock: p. 107.

out further volume therapy he gets spinal anesthesia. Within five minutes his circulation collapses: blood pressure 60, pulse rate 140. The reason: He had hypovolemia, but his hypovolemia was hidden by the sympathetic response – blood pressure increase. The spinal anesthesia made his hypovolemia evident, but only too late.

Premedication in spinal anesthesia: p. 684.

Volume pre-load in serious cases
All the drugs discussed in this chapter – except ketamine – block the sympathetic injury response to some degree, and may cause collapse of the circulation in a hypovolemic patient. Prevent circulatory collapse by flush infusion of 1000-2000 ml Ringer before anesthesia starts.

Do not use spinal anesthesia in patients with unstable circulation.

Sympathetic hyperactivity

The total load upon the war wounded – heavy pain, mental and physical exhaustion, anxiety, strenuous evacuation – creates an over-reaction in the normal sympathetic nervous reponse to injury:
- Gastric irritation, spasms and vomiting
- Heart irritability, tendency to heart arrhythmia
- Increased risk of post-operative organ complications

Atropine may increase the risk of acute hyperthermia in hot countries.

Analgesics and tranquilizers, doses and side effects: p. 151.

Measures to reduce the sympathetic hyperactivity
- **Block the sympathetic response:** Atropine blocks the vagus stimulation o stomach and heart. Thus atropine premedication reduces the risk of aspiration and arrhythmias during anesthesia.
- **Prevent a continuous sympathetic stimulation** by early and effective analgesia. 5-10 mg morphine i.v. as premedication will also reduce the post-operative pain.
- **Reduce the sympathetic stimulation:** Mental support to the patient during evacuation, surgery and the training period. Inform the patient of your plans for surgery and rehabilitation, gain his confidence and active cooperation. Make his family and friends stay with him for support. Good mental support reduces the rate of post-operative complications.

Glucose infusion as basic life support: p. 152.

Hypoglycemia?
Low blood glucose increases the risk of blood acidosis, heart arrhythmia and circulatory collapse. In poor areas patients may arrive for surgery after prolonged evacuations with hypoglycemia and livers empty of glycogen. Also patients with chronic diseases at the time of injury, and exhausted fighters are risk cases.
- Risk cases: Start infusions with dextrose 5%.
- High-risk cases: Consider 500-1000 ml 10-12% glucose infusion in addition to electrolytes during the anesthesia.

Diseases causing anemia: p. 282.

Anemia?
Hemoglobin levels below 6-7 g% due to acute bleeding imply tissue hypoxia and risk of cardiac complications during surgery. Consider autotransfusion or blood transfusion. **Notice** that cases with grave chronic anemia due to diseases or starvation carry less risk of complications.

The complete premedication to major wartime anesthesia
- Effective analgesia: I.v. morphine-type drugs or low-dose ketamine
- Pre-load volume therapy
- Gastric aspiration and i.v metoclopramide to aspiration risk cases
- Adults: I.v. atropine 0.5 mg. Children: I.v. atropine 0.1 mg/10 kg
- Autotransfusion or blood transfusion in hemoglobin levels below 8 g%
- Consider dextrose drip or glucose bolus infusion
- Information and mental support

Side effects of general anesthetics

Halothane (a general anesthetic) has some toxic effect upon the liver, and repeated halothane anesthesia may damage the liver. Optimal liver function is essential for tissue regeneration in extensive injuries. Halothane is not the anesthetic of choice in cases for repeated surgery.

The body responds to major surgery with immune system depression – the body's defence against infections is generally reduced. General anesthesia further depresses the immune system, and the risk of post-operative infections is increased compared to patients managed under local anesthesia. Patients with high-risk score regarding secondary organ complications thus benefit from nerve block or epidural anesthesia.

Ketamine
It may increase the brain edema in head injuries. The effect is slight, and of no practical importance in low-dose analgesia or anesthesia. Also ketamine increases the pressure inside the eyeball which may complicate surgery on penetrating eye injuries. Ketamine increases the blood pressure in hypotensive cases: Use that positive side effect in analgesia and anesthesia. **Notice:** Ketamine may cause circulatory collapse in cases with **prolonged** grave hypovolemia – see p. 149.

Side effects of local anesthetics

The most common drugs are lidocaine (Lignocaine, Xylocaine), and bupivacaine (Marcaine). The side effects do not differ between the different local anesthetics. The side effects depend upon the dose of the anesthetic, and the drugs have different critical doses. We advice you to use as a standard only one or two of the drugs – they will meet all your needs. Adrenaline causes

vasoconstriction. By adding adrenaline to the anesthetic, the duration of anesthesia is increased by 25-50%. The absorption of the drug into the blood circulation is reduced, and so is the risk of side effects. The adrenaline additio allows you to exceed the maximum dose of the anesthetic drug.

Table 1
Maximum doses of local anesthetics – guidelines

Doses in spinal anesthesia: p. 685.

Drug	Onset time	Duration of anesthesia	Max. dos
Lidocaine with adrenaline	rapid	1-2 hours	8 mg/kg
Bupivacaine with adrenaline	moderate	4-6 hours	3 mg/kg

Side effects on the brain

The brain is the first organ to give signals of local-anesthetic overdose. The clinical signs of increasing toxic effect:

- First: numbness of lips and tongue, rapid eye movements (nystagmus) and tinnitus
- Then: mental reactions (confusion, anxiety)
- Then: shivering and convulsions
- Then: circulatory collapse, respiratory depression

Measures

- Free airway procedures
- Oxygen
- I.v. diazepam 10-20 mg against convulsions
- Volume therapy and assisted ventilation in cases of serious side effects

Side effects on the circulation

Clinical signs of hypovolemia: p. 107.

Anesthesia during pregnancy: p. 449.

Systemic absorption of the drugs causes vasodilation: circulatory collapse in hypovolemic patients. In higher doses you may see increased heart rate and heart arrhythmias. **Notice:** Bupivacaine may cause circulatory complications without any signs of brain affection. From lidocaine the first signs of overdose always come from the brain.

Measures

- 1000 ml Ringer as flush infusion
- I.v. ephedrine 10-25 mg in repeated doses in severe hypotension
- Low pulse rate: I.v. atropine 0.5-1 mg

Precautions when using more than moderate doses of local anesthetics

- Infusion running through a good i.v. line.
- Diazepam, ephedrine and atropine at hand.
- Equipment for suction and endotracheal intubation at hand.

Points to note – Chapter 46

All methods discussed in this chapter are simple and safe – as long as the doses and precautions are followed strictly

- do not give local anesthesia unless you have training in the basic life support procedures: p. 137-152
- and unless you have emergency drugs and equipment at hand to manage complications: p. 64-65

For emergency surgery, intermittent i.v. ketamine is the best anesthesia: p. 691

46 Local anesthesia

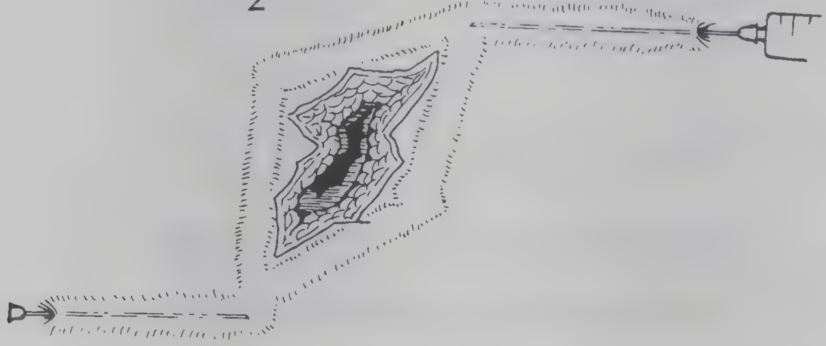
Infiltration anesthesia

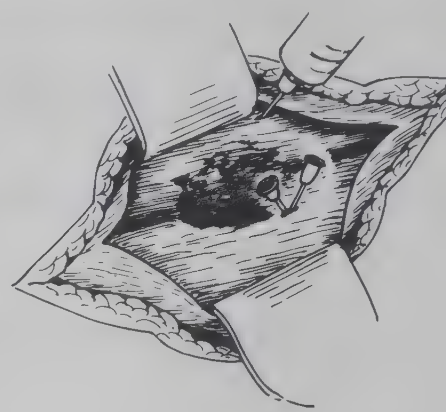
Drugs and equipment
- Lidocaine 0.5% plain or with adrenaline (1:200 000).
- Needles: 0.5 - 0.8 mm.
- Spinal needles (25 G) for extensive or deep infiltration.

1

1 The technique: As the sensory nerves run subcutaneously, the superficia parts of any wound are anesthetized by two subcutaneous injections.

2





2 Infiltration anesthesia for minor debridements: The tissues are infiltr ted layer by layer as the debridement proceeds: infiltration for the skin incision. Then fanwise through the muscle fascia and along the wound track into the muscles. Anesthetic with adrenaline makes it bleed less but makes the assessment of tissue necrosis more difficult.

Maximum doses:
Lidocaine – 5 mg/kg
Lidocaine with adrenaline – 8 mg/kg
Bupivacaine – 2 mg/kg
Bupivacaine with adrenaline – 3 mg/kg

Do not exceed the maximum doses
Better add ketamine 0.25-0.5 mg/kg body weight as repeated i.v. injections. Or dilute lidocaine to 0.3% (with NaCl 0.9%) to affect a wider area not exceeding the toxic dose.

Fracture hematoma anesthesia
The method is effective for field reduction of fractures and evacuation analgesia. The hematoma is punctured. Aspirate blood from the hematoma into the syringe to verify correct position of the needle. Then 10-20 ml lidocaine 1% without adrenaline is injected slowly into the hematoma.

Intercostal nerve block. Pleural analgesia

The nerve block principle
Both motor and sensory functions of any nerve may be blocked at any point between the spinal cord and the peripheral receptors by infiltration of local anesthetic around that nerve. Thus both regional muscle relaxation and regional anesthesia are obtained.

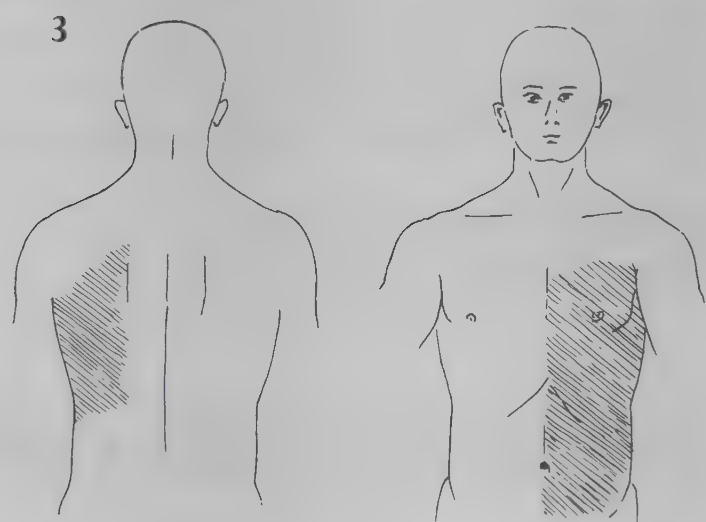
Advantages of nerve blocks
- The equipment is simple, light and inexpensive
- Excellent analgesia during evacuations and after surgery
- Few general side effects within the maximum anesthetic doses
- Well suited for secondary surgery in non-extensive limb cases

Disadvantages of nerve blocks
- They are not as simple as they look: You need much training to make them work
- Not fit for urgent primary surgery: The onset time is 20-30 minutes
- Not fit for extensive injuries or multiple injuries

Intercostal nerve block anesthesia

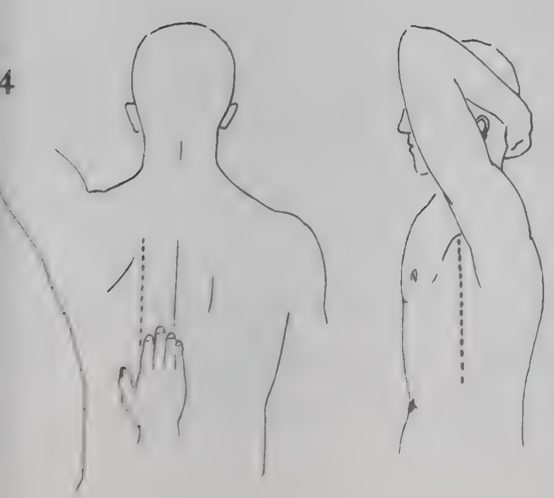
Indications
- Analgesia before and after surgery in chest and high abdominal injuries
- Chest surgery
- Abdominal wall surgery
- Supplement to spinal anesthesia for abdominal surgery, but only in cases where the spinal anesthesia proves insufficient and the patient is circulatory stable (p. 687)

3



3 The anesthetic area: Blocking of costal nerves causes muscle relaxation of intercostal and abdominal muscles as well as anesthesia to below the umbilicus (Th12). **Notice:** There is a risk of toxic overdose of anesthetic in extensive intercostal nerve blocks. Given a maximum total dose of 2 mg/kg bupivacaine, you can only block 8-10 intercostal nerves with 0.5% bupivacaine, 3 ml on each nerve. Adding adrenaline, you may block 10-12 nerves.

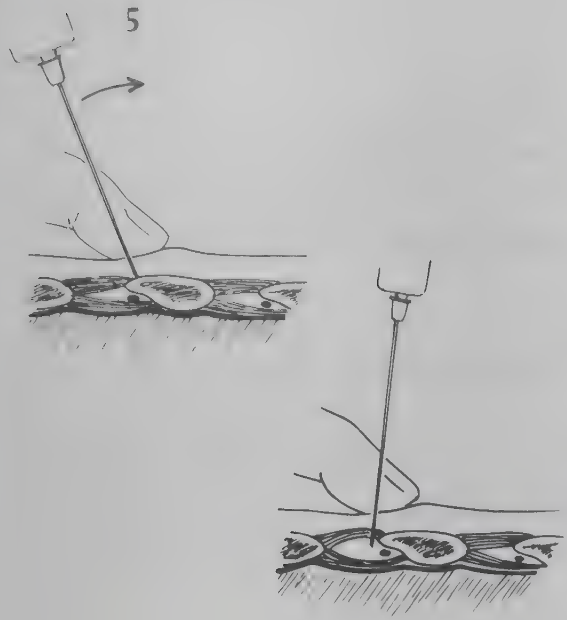
4



Drugs and equipment
- Bupivacaine 0.5% or lidocaine 1.5% with adrenaline, 3 ml for each nerve block.
- Fine-caliber needle (0.5 mm).
- I.v. diazepam or low-dose ketamine for sedation of the patient during application of the nerve block.
- I.v. infusion running, emergency drugs at hand, set for chest tubing at hand.

4 The site of injection: The block is best applied through a posterior approach, three fingers lateral to the spine. A block at this level causes total anesthesia of the chest wall. Or the block may be applied in the mid-axillary line.

5



5 The injection: In a groove on the underside of each rib run the nerve, artery and vein for that segment. Wash the area, palpate the rib and infiltrate little anesthetic in the skin at the lower border of the rib. Forward the needle until it reaches the rib. "Walk" the needle down the rib until it reaches the lower border. From this position forward the needle not more than 5 mm. Aspirate to avoid intravascular injection, and inject 3 ml anesthetic slowly.

Problems with this method
- Note the maximum doses: Use anesthetic with adrenaline in extensive bloc to reduce the systemic absorption and the risk of side effects.
- A sharp chest pain is a sign of pleural puncture or pneumothorax. The fine-caliber needle reduces the risk of significant pneumothorax. Clinical examination for pneumothorax should be routine when the block is done.

Pleural analgesia

Indication
Analgesia for chest-injured with chest tube.

Drugs and equipment
Lidocaine 1% or 2% with adrenaline or bupivacaine 0.5%.

Chest tube management: p. 142.

Intrapleural anesthesia/analgesia may also be applied by using a fine-caliber catheter inserted percutaneously into the pleural space – however, that procedure is not for field use.

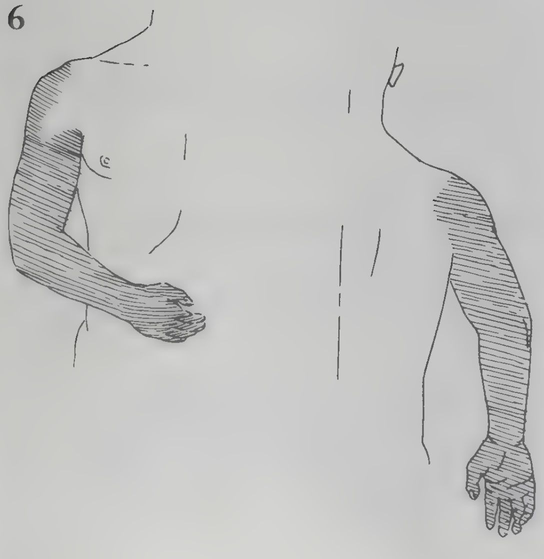
The procedure
The anesthetic solution is applied through the chest tube. The tube is clampec and 20 ml anesthetic is flushed through the chest tube into the pleural space. You may dilute the anesthetic with 20 ml saline for better distribution. After five minutes the clamp is released. Analgesia is rapid and effective.

Problems with this method
None significant.

Brachial plexus nerve block

Indications
Anesthesia for upper limb and shoulder surgery.
Surgical anesthesia will last for 2-3 hours.

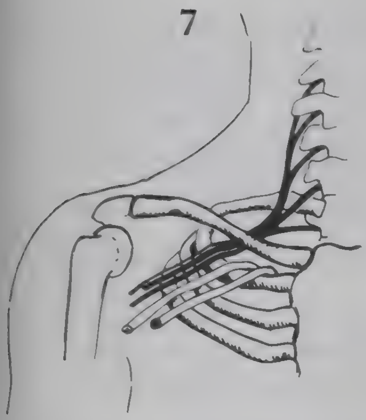
6

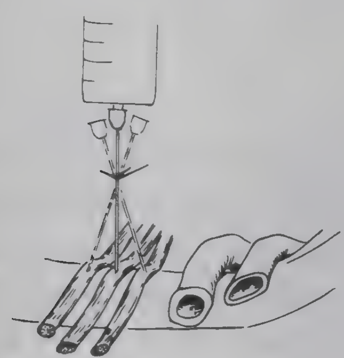


6 The anesthetic area: A complete block of the plexus reaches the shoulder girdle. Often the block is incomplete and the upper parts of the arm are not anesthesized.

Drugs and equipment
- Lidocaine 1% with adrenaline or bupivacaine 0.5% with adrenaline
- Short needle (30 mm) of small caliber (0.5 mm)
- Infusion running, emergency drugs at hand, set for chest tubing at hand

7





7 The procedure: The three main branches of the nerve plexus cross the first rib just posterior to the subclavian artery. As pleura is immediately under the first rib, the injection is directed towards the rib to avoid pneumothorax.

Turn the head to the opposite side. Tell the patient to raise the head a little for you to locate the posterior border of the sternocleidomastoid muscle. Walk your finger along the muscle in distal direction and locate the subclavian artery pulse beat by deep palpation. This is the site of entrance. Wash the area. Infiltrate a little anesthetic in the skin and seek the first rib posterior to the artery with your needle. The distance down to the rib is approximately 2-3 cm. If you let the needle "walk" upon the rib all the time, the risk of pneumothorax is minimal.

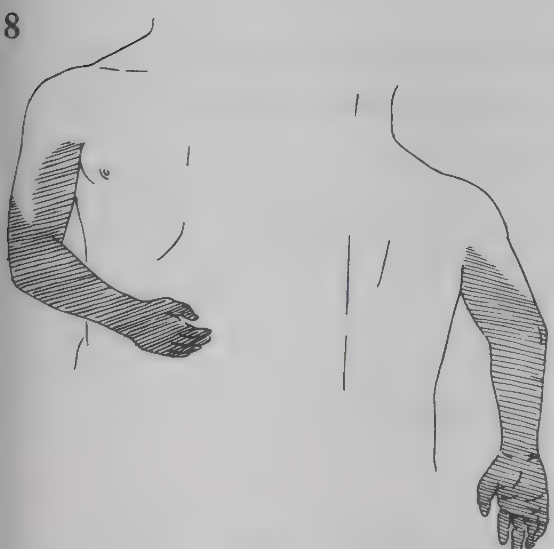
Let the needle "walk" forwards upon the rib, while you aspirate the syringe. Tell the patient to inform you when he feels radiating sensations down his arm: That sensation indicates that the needle point has touched one of the nerves; you can start the injection. Inject 30 ml lidocaine 1% slowly fanwise towards the rib. If you cannot exactly locate the nerves, seek the artery with your needle.

If you aspirate blood, you have hit the artery (fine-caliber needle, no problem). Then "walk" 1 cm in the posterior direction and start the injection of 40 ml anesthetic. After 10-20 minutes the anesthesia is complete.

Better use axillary block if you cannot monitor the patient properly.

Problems with this method
- Poor anesthesia of the ulnar nerve (ill 10) is common. You may add ulnar nerve block at the elbow.
- Pneumothorax due to perforation of the top of pleura (especially in patients with pulmonary tuberculosis). The risk is reduced when you use short fine-caliber needles. Routine: Clinical chest examination or X-ray after the nerve block.
- Horner's syndrome (dilation of one pupil) and recurrent laryngeal nerve block (hoarse voice) is not serious and the patient's condition returns to normal within 2-4 hours.

8



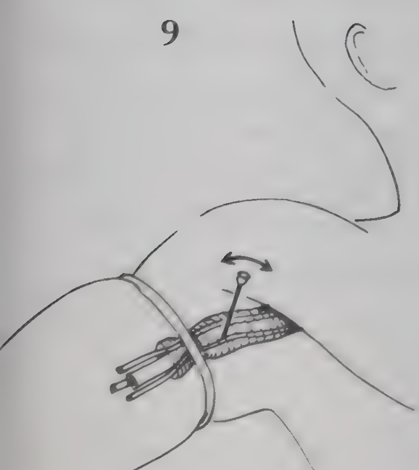
Axillary nerve block

Indication
Anesthesia for lower arm and forearm surgery.

8 The anesthetic area.

Drugs and equipment
- Lidocaine 1% with adrenaline or bupivacaine 0.5%
- Fine-caliber needle (0.5 mm)
- Infusions running; emergency drugs at hand

9



9 The procedure: The nerves to the arm and forearm run inside a fascial sheath together with the axillary artery and vein. The anesthetic must be instilled inside this sheath. The patient is lying with his arm abducted at 90 degrees and his forearm rotated outwards. Apply a **slight** tourniquet to prevent the

anesthetic from running distally in the sheath, and wash. Palpate the artery pulse beat, infiltrate a little anesthetic in the skin, and pass the needle just above the artery in a slightly proximal direction. **Notice:** The artery and nerv are not running close to the skin. Remove the syringe and look: If the needle pulsates together with the pulse beat, the position is approximately correct. Now search the position where the needle point causes radiating sensations down the arm: You have located the nerve exactly, and the anesthesia will be more complete. Inject 30 ml of the anesthetic slowly without changing the position of the needle. Aspirate frequently to avoid intravascular injection. Leave the tourniquet for 10 minutes. After 30 minutes the anesthesia is complete.

Problems with this method
- Approach through the artery: The radial nerve runs behind the artery, and the anesthesia of the radial part of the forearm may be poor. In that case you may repeat the radial block in the axilla through the artery: Locate the arter and forward the needle through it until you cannot aspirate blood into the syringe. In that position, immediately behind the artery, inject 10-15 ml anesthetic without adrenaline. Or you may supplement a poor block with local infiltration or ketamine low-dose i.v. anesthesia.
- In fat patients the location of the artery may be difficult. Then go for radiating sensations with your needle to locate the nerve bundle.

Nerve block of the hand

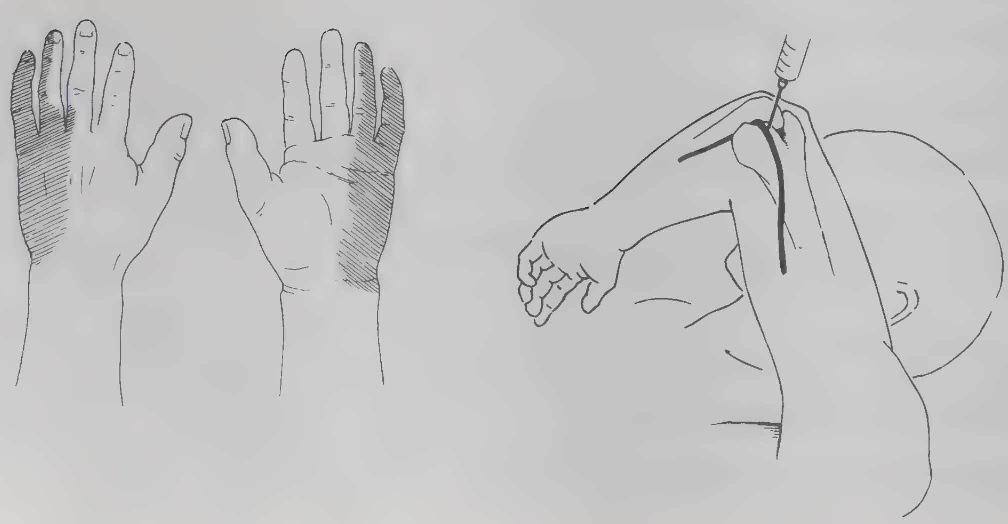
Motor function of the three upper limb nerves: p. 499-500.

The hand is innervated by three main nerves, the ulnar, radial and the median nerves. The three main nerves are blocked separately above hand level. Or their branches are blocked at the base of the fingers.

Indication
Anesthesia for hand surgery.

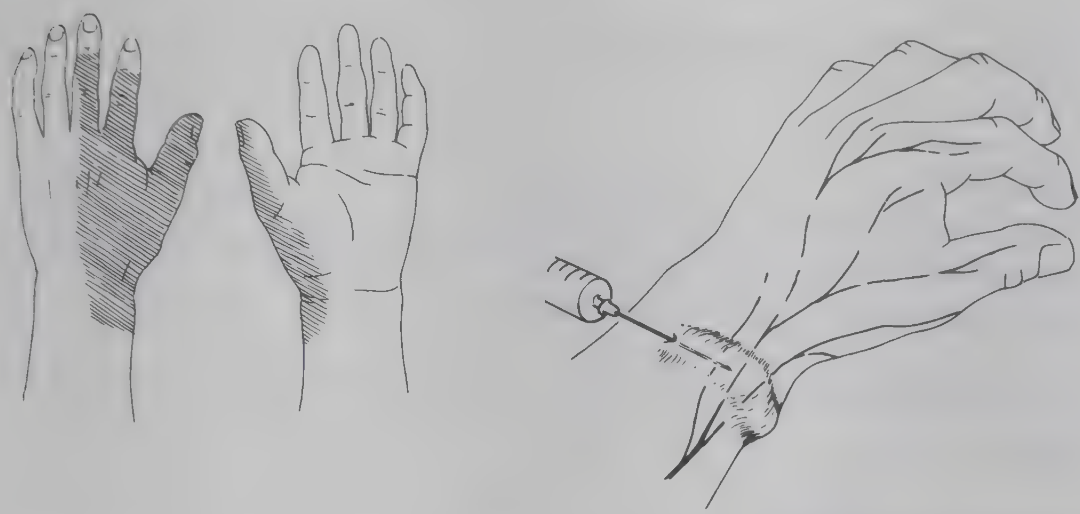
Drugs and equipment
- Lidocaine 1% with or bupivacaine 0.5% adrenaline.
- Fine-caliber needle (0.5 mm).

10



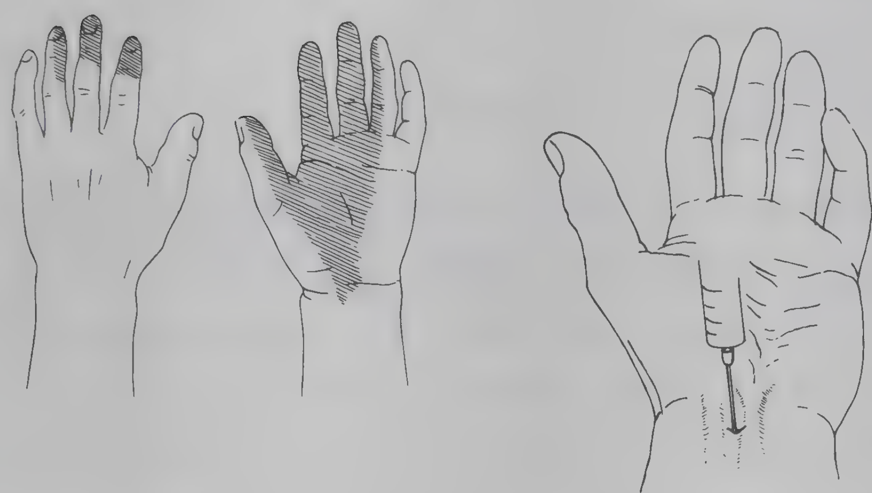
10 Hand block – ulnar nerve: Palpate the nerve in its bone groove just behind the medial epicondyle at the elbow; you can feel it slipping under your finger. Wash and inject 10 ml anesthetic under the skin at the nerve. The onset time is 10-30 minutes.

11



11 Hand block – radial nerve: Just proximal to the wrist the branches of the radial nerve spread fanwise. Inject 5-10 ml anesthetic as a subcutaneous wall. The latency before the "take" is 10 minutes.

12



12 Hand block – median nerve: The nerve runs together with the finger flexor tendons under the palmar tendon approximately 2 cm under the skin. The site of injection is between the palmar tendon and the radial flexor of the wrist. Inject a little anesthetic in the skin and seek fanwise with your needle for sensations radiating into the 2nd and 3rd fingers. Inject 5 ml anesthetic at the nerve.

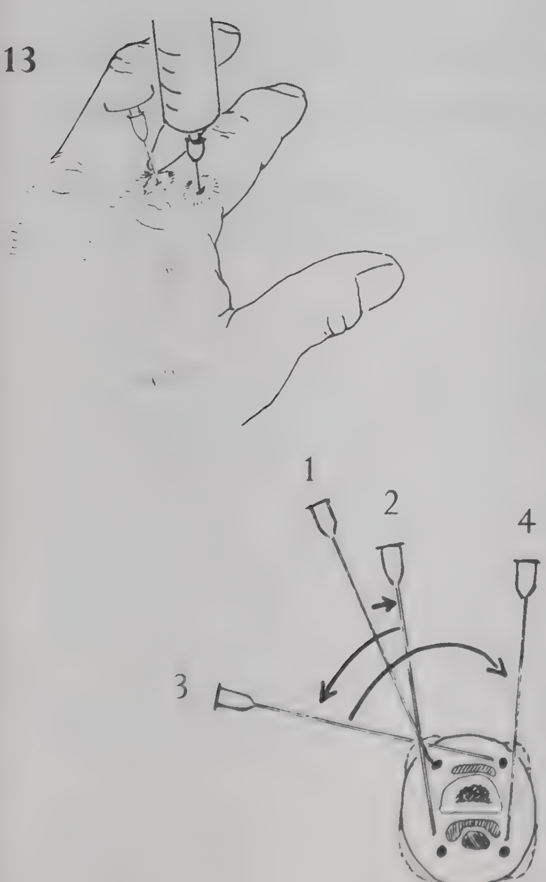
Problems with this method
None in particular.

Finger nerve block

Indication
Anesthesia of one or several fingers.

Drugs and equipment
Lidocaine 1% or bupivacaine 0.5% without adrenaline.

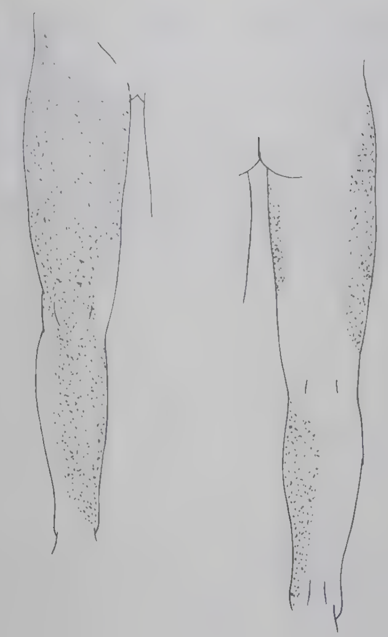
13



13 The procedure: There are four nerves for each finger, two dorsal nerves just under the skin, and two volar nerves close to the flexor tendons. Puncture one: First inject 2 ml anesthetic at one dorsal nerve (1). Then forward the needle close to the bone and inject 3 ml anesthetic immediately volar to the bone (2). Withdraw the needle, cross the finger and inject another 2 ml anesthetic at the second dorsal nerve through the same puncture (3). Remove the needle. Puncture two: Blocking the volar nerve on the opposite side (4).

Problems with this method
None significant.

14



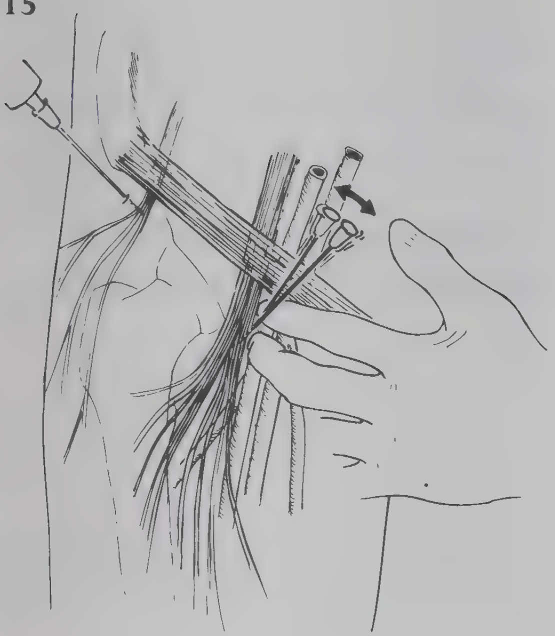
Femoral nerve block

Indications
- Anesthesia of donor sites for skin grafting
- Analgesia of femur fractures and thigh injuries during the evacuation
- Anesthesia for minor lower limb surgery

14 The anesthetic area (anesthesia of the lateral cutaneous nerve of the thigh is included).

Drugs and equipment
- Lidocaine 1% or bupivacaine 0.5%
- Fine-caliber needle (0.5 mm) 50 mm
- Infusion running, emergency drugs at hand

15



15 The procedure: The main femoral nerve is located just lateral to the femoral artery, 1-2 cm deeper than the artery. Wash the field. Palpate the artery pulse beat. Infiltrate the skin with a little anesthetic, and forward the needle just lateral to the artery. Remove the syringe: If the needle pulsates with the pulse beat, the position is correct. Forward the needle another 1-2 cm, and infiltrate fanwise 20 ml of the anesthetic. Aspirate repeatedly to avoid intravascular injection. If the artery is punctured, apply manual pressure for five minutes to prevent hematoma formation – then repeat the procedure.

The lateral cutaneous nerve of the thigh is located under the inguinal ligament 1-2 cm medial to the anterior iliac spine, and under the muscle fascia of the thigh (fascia lata). Wash the field and infiltrate the skin. Forward the needle slowly, you will feel the resistance of the fascia lata when you penetrate it. Infiltrate 10 ml anesthetic fanwise in medial direction.

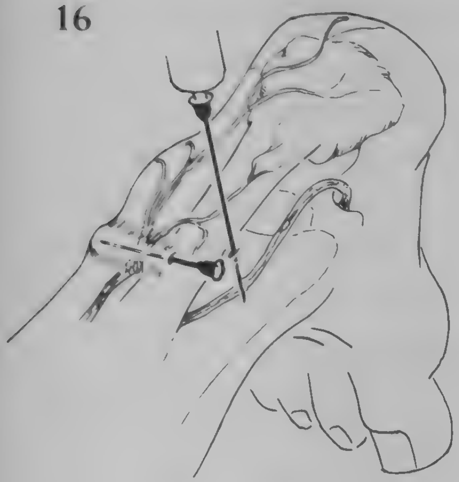
Problems with this method
- Perforation of the femoral artery is no problem as long as it is recognized, and a fine-caliber needle is used. Manual pressure for five minutes prevents hematoma formation.
- If the anesthesia is poor in the deeper structures, supplement with ketamine low-dose anesthesia.

Nerve block of the foot

Indications
- Anesthesia for foot surgery
- Analgesia during evacuation

Drugs and equipment
- Lidocaine 1% or bupivacaine 0.5% with adrenaline
- Fine-caliber needle (0.5 mm)

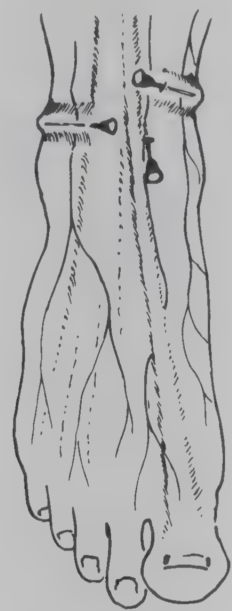
16



16 Blocking the posterior nerves: Five nerves are blocked separately, two of them by a posterior approach. **The lateral posterior nerve** runs subcutaneously; it is blocked by a subcutaneous wall of maximum 10 ml anesthetic. **The medial posterior nerve** runs deep upon the posterior surface of tibia medial to the Achilles tendon together with the posterior tibial artery and the flexor tendons. To locate the medial nerve, forward the needle towards the posterior surface of tibia behind the artery. Inject maximum 10 ml anesthetic, aspirating now and then to avoid intravascular injection.

With a careful technique you should make the total ankle block with 30 ml anesthetic.

17



17 Blocking the anterior nerves: The lateral and medial nerves both run subcutaneously. **The deep peroneal nerve** innervating the first toe is located deep upon the anterior surface of tibia just lateral to the first toe's extensor tendon. The lateral and medial anterior nerves are blocked by a subcutaneous wall of maximum 10 ml anesthetic each. The first toe extensor is identified ("raise your toes!"), radiating sensations are sought just medial to this tendon and maximum 10 ml anesthetic injected.

Problems with this method

Incomplete anesthesia in some areas: Supplement with toe nerve block or local infiltration anesthesia.

Toe nerve block

The technique is identical to the finger nerve block (ill 13).

Regional intravenous anesthesia

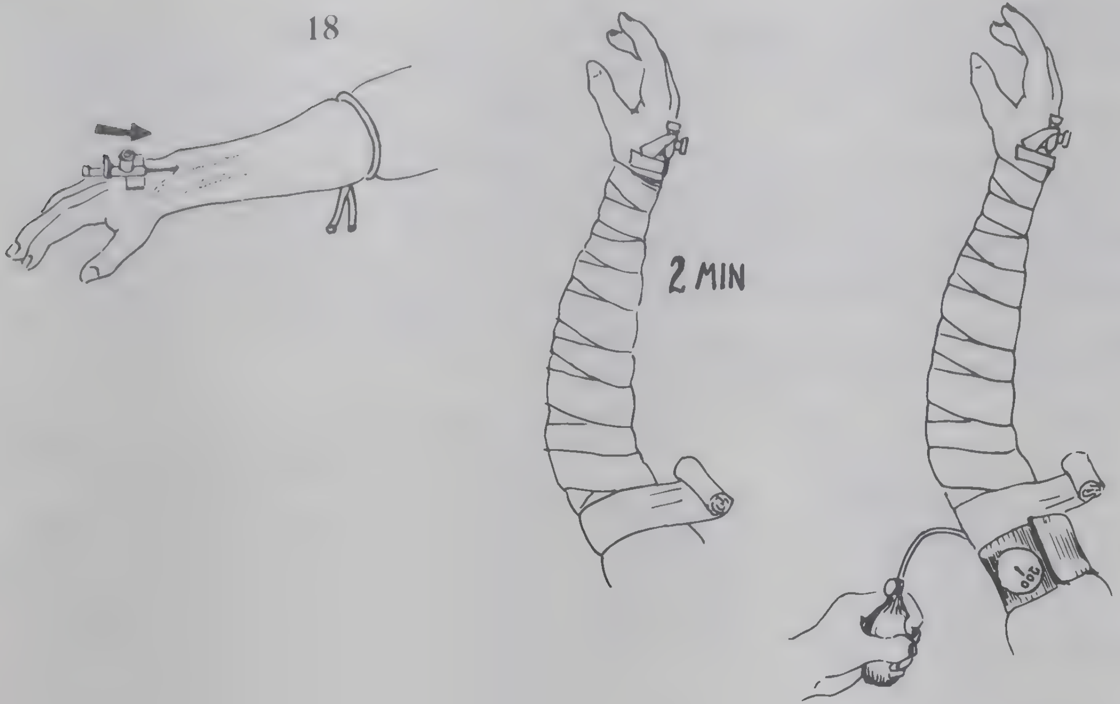
Indications

Anesthesia for bloodless field surgery of upper and lower limbs. The duration of anesthesia is less than two hours.

Drugs and equipment

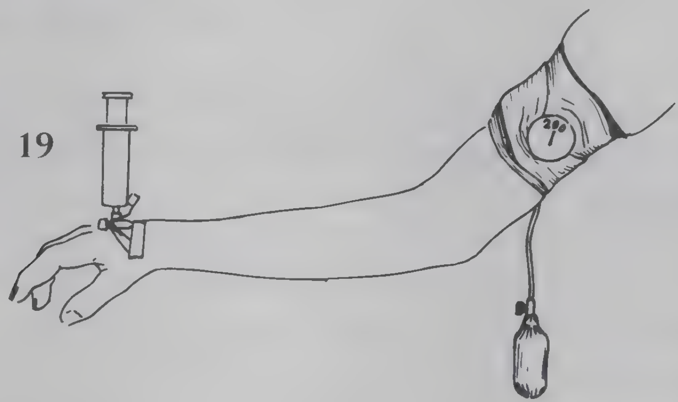
- Lidocaine 0.5% without adrenaline
- Pneumatic tourniquet, or blood pressure apparatus and crepe bandage
- I.v. cannula
- Infusion running on the opposite limb, emergency drugs at hand

18



18 The bloodless field: Insert an i.v. cannula in a vein at the wrist or distal on the forearm. Empty the limb of blood by elevation for two minutes, and by wrapping a tight elastic bandage from distal to proxi- mal direction. Keep the arm with th tight bandage elevated until a BP apparatus is applied on the arm with cuff pressure at least 200 mm (100 mm above the systolic blood pressure).

19



19 The anesthesia: Unwrap the arm. Tell one of your assistants to watch the BP apparatus continuously and maintain the cuff pressure at 200 mm. Inject slowly 50 ml anesthetic in the i.v. cannula. After 10-15 minutes the anesthesia is complete. Do not remove the i.v. cannula until the anesthesia is complete: You may have to add another dose of anesthetic (see below). **Lower limb regional anesthesia** may be difficult due to insufficient tourniquet despite high cuff pressure: Insert the cannula in a foot vein or distal in the saphenous vein. Take care to apply the BP-cuff well distal to the knee joint to avoid pressure damage on the peroneal nerve. In muscular males a cuff pressure of 300 mm and more than 50 ml anesthetic may be needed (leaking of anesthetic into the intraosseous space). Otherwise the procedure is identical to that of upper limb regional anesthesia.

Problems with this method

- Bloodless fields increase the risk of thrombosis.
- Maximum duration is two hours: A bloodless field standing more than two hours will cause local necrosis due to hypoxemia.
- Not fit for debridements: You cannot assess tissue viability.
- Side effects are common when the cuff is released, but they recede rapidly without intervention. **Notice:** Never release the cuff during the 15 minutes after the injection of anesthetic.
- As the cuff pressure is painful, either add a low-dose ketamine anesthesia or use the two-cuff method: A second cuff below the first is inflated to 200 mm once the skin is anesthesized, and the first cuff deflated.
- Delay of onset: Anesthesia of periosteum is not complete until 20 minutes after injection of the anesthetic.

Points to note – Chapter 47

Do not start training in spinal anesthesia unless you are trained in basic life support, and are guided by experienced staff

- note the difference in effect and doses of plain and "heavy" bupivacaine solutions
- know the precautions when you use spinal anesthesia: p. 684. It must not b
  used in circulatory unstable cases
- precautions in pregnant women: p. 449

47 Spinal anesthesia

Spinal anesthesia is a type of nerve block: The anesthetic is injected into the dural sac where it mixes with the spinal fluid. The nerve roots are thus block inside the dural sac.

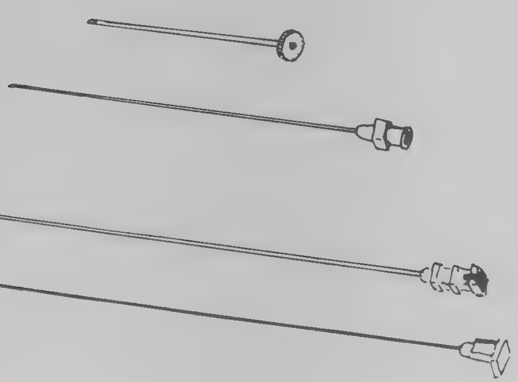
Indications
- Pelvic and lower limb surgery
- Abdominal surgery

The anesthetics

Both lidocaine and bupivacaine may be used as spinal anesthetics. Their onset time is approximately the same (5-10 minutes). As the duration of lidocaine anesthesia is one hour – compared to the 3-4 hours with bupivacaine – our advice is to use **bupivacaine as the standard spinal anesthetic in wartin surgery.** The spinal anesthetics are available as two different solutions – with different action:
- **"Heavy" solutions:** Both "heavy" lidocaine 5 mg/ml and "heavy" bupivacaine 5 mg/ml are available. Glucose 5 mg/ml is added to the anesthetic to make a solution with specific gravity higher than the spinal fluid. (You may make the heavy solutions yourself by simply adding 5% glucose.) The heavy solutions do not spread by diffusion inside the spinal fluid. Their localization – and the nerve roots affected – is determined by the position of the patient The anesthetic area is therefore easier to predict compared to the plain solutions. Heavy bupivacaine 5 mg/ml is the spinal anesthetic of choice for abdominal surgery.
- **Plain solutions:** Bupivacaine 0.5% (without glucose) spreads inside the spinal fluid by osmotic gradient. It is the spinal anesthetic of choice for all pelvi and lower limb surgery. But the upper level of anesthesia is too unpredictabl for abdominal surgery.

Bupivacaine anesthesia: Wait 20 minutes before surgery starts to stabilize the anesthetic effect.

1



1 Spinal needles: Fine-caliber spinal needle with introducer. (You may equally use a 25 G spinal needle and an ordinary 22 G injection needle as introducer). And a standard spinal needle diameter 22 G with stylet.

Premedication
- Drugs: I.v. diazepam 5 mg. Or i.v. morphine 5 mg plus i.v or i.m. atropine 0.5 mg.
- Fluid pre-load: Give one flush infusion of 500-1000 ml Ringer immediately before the anesthesia to prevent circulatory collapse.
- Never give spinal anesthesia unless the BP value (after the flush infusion) is higher than the PR value. Eg: Blood pressure 90, pulse rate 100 → high risk of circulatory collapse, use ketamine anesthesia. Eg: Blood pressure 100, pulse rate 90 → you may give spinal anesthesia, give i.v. ephedrine 5-10 mg as prophylaxis immediately before the anesthesia.
- Inj. ephedrine, emergency drugs and intubation set at hand.

Management of circulatory collapse: p. 687.

Table 1
Dose and anesthetic level by injection at L3-L4

Intended level	Lidocaine/bupivacaine heavy 5 mg/ml	Bupivacaine plain 0.5 mg/ml
Th12	1.5-2 ml	3-4 ml
Th4	2.5-4 ml	unpredictable

kinny patients need higher doses of lain spinal anesthetic. Fat patients nanage with less.

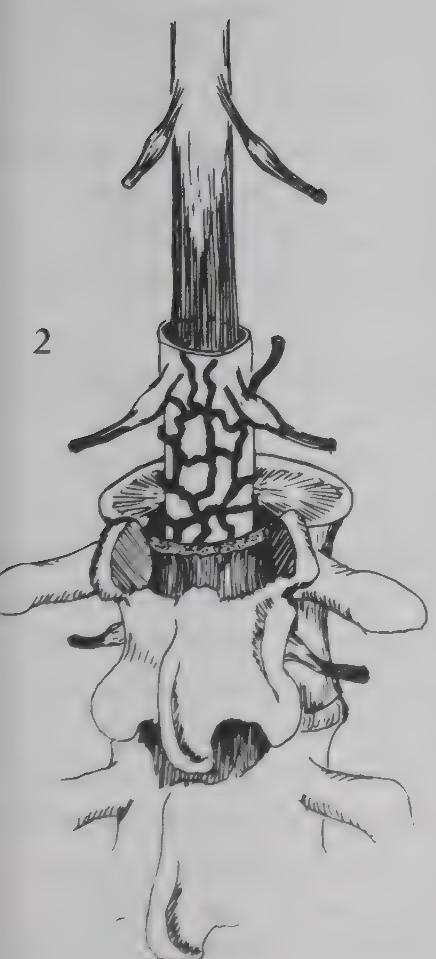
Table 2
Anesthetic level and surgery

Type of surgery	Minimum level of anesthesia
Abdominal	Th4
Pelvic	Th10
Thigh	L1
Lower limb	L3 (the knee)
Perineal	S2 (perineum)

bdominal surgery under "low"spinal nesthesia (below Th6) increases the isk of bradycardia and arrhythmias.

Notice the landmarks:
Th4 - the nipples
Th6 - the lower end of sternum
Th10 - umbilicus
Th12 - the pubic bone (midline)

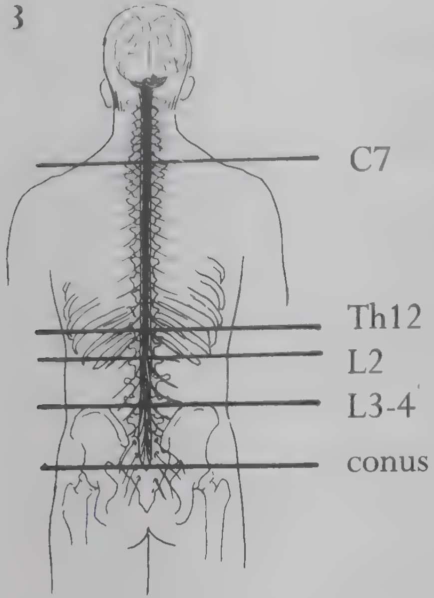
2



The procedure

2 **The anatomy:** The spinal cord with the spinal fluid is located inside the dural sac. At each vertebra two nerve roots of the cord leave the spine. The dural sac is well protected inside the bony spinal canal, and by a strong ligament ("the yellow ligament") between the spinous processes of each vertebra (you may feel this ligament when you penetrate it with the spinal needle). Immediately outside the dural sac – in the epidural space – is a venous network. Slightly bloody spinal fluid by the needle indicates that you have accidentally hit one of the small veins. The bleeding stops spontaneously and is not regarded as a complication. **Notice:** Let the puncture of the dural sac be as non-traumatic as possible to avoid leaking of spinal fluid – a cause of post-spinal headache.

3

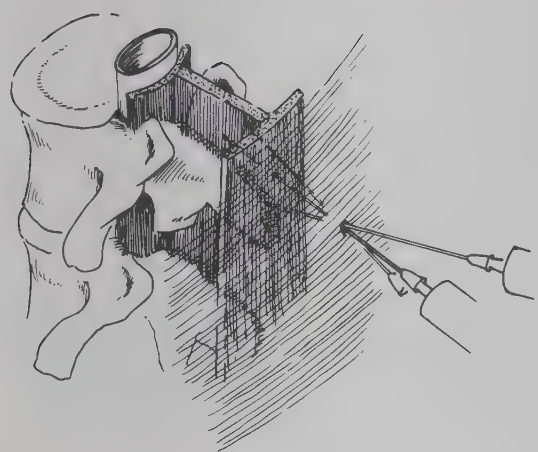


3 Spinal landmarks: The spinal cord ends at L2, and the level of puncture below the L2 vertebra to avoid needle damage to the cord. Below L2 is a "ho tail" of spinal nerves that slip off the needle point without being damaged. A common site for the injection is between the 3rd and 4th lumbar vertebrae (L L4): A line between the top of his pelvic wings intersects the spine approxima ly at this level. The end of the dural sac (conus) is within the sacrum. Serious complications arise if the anesthetic reaches his cervical spine – C7.

4

4 The procedure: The patient in sitting position, his spine well curv- ed, not moving (support him). This position gives the most easy access between the lumbar vertebrae. Or the patient may lie on his side, his spine maximally curved. Good light is essential. Locate his pelvic wings and identify and mark the level between L3 and L4 exactly in the midline. Wash well and work sterile from now on.

5

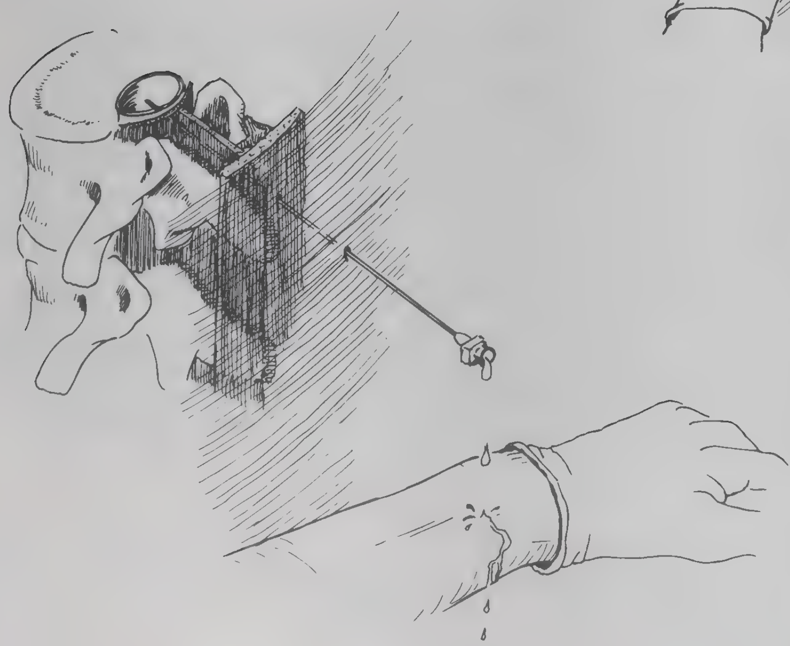


5 For the inexperienced: With an ordinary needle infiltrate local anestheti in the skin at the injection site, and into the interspinal ligament. By fanwise injections you can "feel" with the needle the spine of the vertebrae and thus identify the correct track for the spinal needle.

6

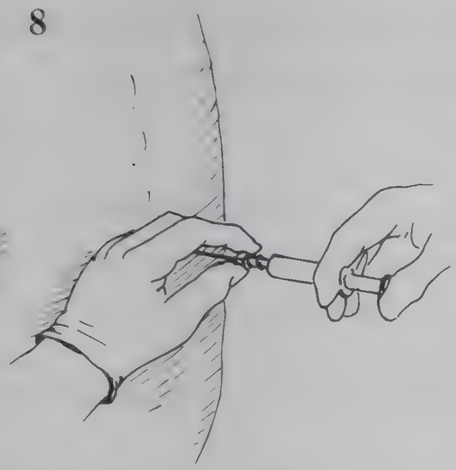
6 The puncture: The spinal needle with the stylet (or fine-caliber needle with introducer) is driven exactly in the midline in a slightly cranial direc- tion. If you hit bone, withdraw and change the direction slightly. Perfora- tion of the thick yellow ligament immediately outside the epidural space may be felt like a small "snap".

7



7 Correct position of the spinal needle: When you are inside the dural sac, withdraw the stylet and wait some seconds for the clear, yellow, 37-degree warm spinal fluid to drip from your needle. If it does not drip, insert the stylet and drive the needle in about 1 mm more, and try again. The structures passed by the needle from the skin inwards: the subcutaneous tissue, the supraspinous ligament, the intraspinous ligament, the yellow ligament, the epidural space and the dural sac.

8



8 **Choose drug and dose – case 1:** Let us say you have a penetrating pelvic injury for exploration. The anesthesia should reach the lower abdomen, Th10-12. The patient is an adult of medium weight. Aspirate **4 ml plain bupivacaine 0.5 mg/ml** in a syringe, withdraw the stylet from the spinal needle, connect the syringe and aspirate a little spinal fluid to check the correct position of the spinal needle. Inject the anesthetic slowly, remove the needle, apply a small bandage – and let the patient lie down. **Notice:** If you let the patient sit for 2-4 minutes after the anesthetic is applied, the anesthetic area increases.

Choose drug and dose – case 2: A penetrating abdominal injury for exploration. The anesthesia should reach Th4. Inject **4 ml heavy bupivacaine 5 mg/ml** using the same procedure. Lay the patient in the supine position immediately after the injection, tilt the table slightly head down – but check that his neck is flexed on a pillow so the anesthetic cannot "flow up" to the cervical spine.

Monitor closely after the injection:

- **The circulation:** Pulse rate and blood pressure every two minutes for 15 minutes. Normally the blood pressure will fall somewhat within 2-5 minutes, then begin to rise when surgery starts.
- **The respiration:** In high thoracic anesthesia (anesthetic level above Th6) the patient feels discomfort due to paralysis of the intercostal muscles – the thoracic respiration becomes weak. If the anesthesia reaches the cervical level, also the voice becomes weak – he may not even be able to whisper as he cannot force air to pass between the vocal cords.
- **The upper level of anesthesia:** Ask the patient if he feels his legs becoming "hot". This is a first sign of effective anesthesia. Identify the exact upper level of anesthesia by needle prick test.

Problems with spinal anesthesia

Circulatory collapse

The higher the level of anesthesia, the higher the risk for circulatory complications. If blood pressure falls to 80 mm, or does not rise when surgery is started:

- Flush the i.v. infusion
- I.v. ephedrine 10-20 mg
- Consider flush infusion of plasma expander
- Monitor his heart for arrhythmia
- Reassess his circulatory state after the injury: How much fluid was given during the evacuation? You may have underestimated his blood loss, missed some bleeding internal injury

…lume effect of plasma expanders: … 147-148.

Respiratory depression

The higher the anesthetic level, the higher the risk of respiratory failure.

- A weak or whispering voice indicates high thoracic anesthesia: Give oxygen
- No thoracic respiration: Give oxygen. Consider assisted SIB ventilation

…ssisted ventilation: p. 141.

Endotracheal intubation: p. 137.

- Hoarseness of the voice (vocal cord paralysis) indicates cervical anesthesia: Assisted SIB ventilation and oxygen. Consider endotracheal intubation.

Post-spinal headache

It may develop the first 24 hours after anesthesia. The reason is leaking of spinal fluid through the dural puncture/punctures. The headache occurs mos in patients where you had several "dry taps", withdrawing and reinserting the spinal needle – and in young patients. Preventive:

- Fine-caliber spinal needles with introducer will reduce the risk of post-spina headache.
- A careful technique of puncture – good premedication is essential. An old dogma says 24 hours strict bed-rest after spinal anesthesia should reduce the risk of post-spinal headache – that is not so.

The management:

- Bed-rest: The supine position reduces the headache when it is already established.
- Effective analgesia.
- Fluid load: Per oral or i.v. 3000 ml/day.
- All cases with post-spinal headache, even the bad ones, recover spontaneous within two weeks. The epidural blood patch procedure is not indicated unle the anesthesiologist is experienced and the conditions very clean.

Spinal infection

This infection is a catastrophe that may cause permanent cord damage. Preventive:

- Never make spinal puncture in a wound field or through damaged skin.
- Spinal anesthesia is not the method of choice in a hurried, chaotic and unclean emergency setting.
- Careful sterilization of instruments and strictly sterile procedures are mandatory.

The management consists of high-dose broad-spectrum antibiotics on suspicion.

Anesthesia chart: p. 53.

Anesthesia chart

Spinal anesthesia is an invasive procedure with serious potential complications. The documentation in the chart should be exact, and include the following information:

- The level of spinal puncture
- Puncture problems, if any
- The anesthetic drug and volume
- The upper level of anesthesia
- All side effects and complications

Points to note – Chapter 48

Do not give ketamine anesthesia unless you are trained in basic life support, and have emergency drugs and equipment at hand

- note that as ketamine stimulates the circulation, it is useful as field analgesic But it may have serious side effects in major injuries: p. 149
- know the doses of ketamine analgesia: p. 692
- know the doses of ketamine anesthesia: p. 692

48 Intermittent ketamine anesthesia

Ketamine is the standard wartime general anesthetic.

Advantages:
- A potent analgesic effect
- Rapid action
- No effect on the reflexes of pharynx and larynx (swallowing and coughing), no increased risk of airway aspiration
- It seldom affects the respiration
- It causes blood pressure and pulse rate increase, a positive effect in circulatory shock cases
- It stores well at room temperature
- The cost is reasonable (cheap brands are available)

Disadvantages:
- Mental side effects are common
- It may cause circulatory collapse in patients with a **prolonged** case of hypovolemia

Intermittent ketamine anesthesia – indications

Anesthesia for all kinds of surgery that do not require muscle relaxation
- In combination with muscle relaxants in continuous i.v. anesthesia
- Supplement to incomplete nerve blocks, spinal and epidural anesthesia
- Analgesia after surgery and during major dressings
- Analgesia in the combat field and during evacuation of serious cases, particularly in cases of circulatory shock
- Analgesia before and during release of trapped patients
- I.m. analgesia and anesthesia in infants and small children

Lengthy circulatory shock – use ketamin with care: p. 149.

Doses

Ketamine is available in solutions of 10 mg/ml (for i.v. use) and 50 mg/ml (for i.m. use). For field use the concentrated solution is the standard: 1 ml ketamine solution is diluted in the syringe with 4 ml NaCl 0.9% to a ketamine solution of 10 mg/ml which is standard for i.v. anesthesia.
- **Low-dose ketamine analgesia (minor surgery):** I.v. ketamine 0.5 mg per kg body weight or i.m. ketamine 1-2 mg per kg body weight.
- **Standard dose i.v. ketamine anesthesia (major surgery):** I.v. ketamine 1-2 mg per kg body weight.
- **Standard dose i.m. ketamine anesthesia (children):** I.m. ketamine 5-10 mg per kg body weight.

Always diazepam with the first dose of ketamine.

Precautions

- Premedication: I.v. diazepam 5 mg and i.v. atropine 0.5-1 mg (adult dose) can be given in one syringe together with the ketamine start dose.
- Infusion running, emergency drugs, face mask, self-inflating bag, and endotracheal intubation set at hand.

- In comatose or semi-comatose patients: Endotracheal intubation and gastric aspiration prior to anesthesia.

Monitor continuously during the anesthesia

Assisted ventilation: p. 141.

Head-tilt and jaw-thrust maneuver: p. 136.

- **The respiration:** I.v. ketamine always causes some respiratory depression in the start dose, in some cases even heavy respiratory depression. Be ready to start assisted ventilation.
- **Free airway:** The uncomplicated ketamine patient maintains spontaneous respiration and the reflexes, but not necessarily a free airway.
- **The circulation:** Monitor closely the blood pressure and pulse rate.
- **The analgesia:** Much unrest and shouting during the anesthesia indicate incomplete anesthesia – increase the dose of anesthetic.

Case study – intermittent low-dose ketamine analgesia: A burn patient for debridement, body weight 80 kg.
- Avoid painful manipulation of his injury before anesthesia is complete.
- Give premedication i.v. diazepam-atropine (may be given in one syringe together with the start dose of ketamine).
- Give i.v. ketamine slowly (within 60 seconds). The start dose: 80 kg × 0.5 = 40 mg ketamine. Within 60 seconds the anesthesia is complete and surgery may start.
- The duration of one i.v. dose of ketamine is 5-15 minutes. Signs of pain: The start dose or less is repeated as an i.v. maintenance dose with no risk of cumulation.

Case study – intermittent standard ketamine anesthesia: Double lower limb amputation for primary surgery, body weight 60 kg.
- Premedication: I.v. diazepam-atropine.
- Start-dose ketamine: 60 kg × 2 = 120 mg i.v.
- Maintenance dose: 60 mg ketamine as intermittent injections.

Circulatory shock cases: Muscle blood circulation is poor, absorption of i.m. drugs slow – and the effect of i.m. ketamine unpredictable. Use i.v. drugs!

Case study – i.m. ketamine anesthesia: A ten-year-old child, limb crush injuries with multiple fractures, body weight 30 kg.
- Premedication: I.v. diazepam 5 mg and atropine 0.5 m.
- Start-dose ketamine: 30 kg × 6 = 180 mg i.m. The anesthesia is complete within three minutes.
- The duration of one i.m. dose is 10-25 minutes. Signs of pain: Maintenance dose i.m. 50% of the start dose, 90 mg. **Or** establish an i.v. line after the i.m. start dose and continue with intermittent i.v. anesthesia.

Problems with ketamine anesthesia

Mental side effects

The patient may have rapid eye movements, hallucinations and bad dreams, and show unrest. These are common side effects, and do not necessarily indicate pain or incomplete anesthesia. The disturbances can be prevented to some degree by diazepam premedication. The setting at the operating table should be quiet; do not touch the patient until the anesthesia is complete. If possible keep

the patient in a silent and dark room for recovery. **Notice:** Do not mistake shouting and unrest to be ketamine side effects only – the ketamine cases nee active analgesia when the ketamine effect is running out. Add i.v. pentazocin or morphine when surgery is finished.

Larynx spasm

The patient develops grave stridor during inspiration and turns cyanotic. The complication is not common, but may occur after the ketamine start dose – especially so if the i.v. ketamine is given too rapidly. Measures: Try to ventilat him with bag and face mask. Even without therapy the spasm recedes spontaneously within 1-2 minutes when the cyanosis becomes grave enough.

Heavy salivation

This is common, especially in children. Saliva may obstruct the airways. Atropine premedication is essential. Also consider atropine refill during surgery.

Appendix 1
Management quality control

Why quality control programs

Experience is the best teacher, so also in injury management. To identify the weak points and introduce improved procedures, all clinics should run quality control programs, the one-man mobile clinic as well as major stationary clinics. But improvements can only be done on a scientific base. Thus the medical experience should be collected in a systematic and exact way, that is, by a program agreed upon.

Compared to other fields of medicine, many procedures of wartime surgery survive by force of habit, procedures that surely will be left behind when quality control programs can document their poor results. There are several standard quality control programs available to monitor and compare the results of injury management. But those programs are very elaborate, and designed to fit major, well-equipped, civilian city hospitals. In most forward field clinics there is neither time nor resources to implement extensive control programs. For our purpose control programs must be simplified.

Third World health workers have a vast experience in wartime injury management, experience that should be collected scientifically, and distributed internationally so that results may be compared, and procedures discussed on a sound base – so that we can all gain in skill. To make that possible, we propose an outline for a quality control program simple enough to be implemented, even in a difficult wartime setting with high casualty loads. It is simply based on the information collected from the standard Injury Chart for each patient.

Injury Chart: p. 52.

Outline of the control program

We want to monitor complications in relation to the overall physiological impact of the injury and the localization and severity of the injury. To do that, we must collect three types of information:

- **1 – The results:** Depending upon the aim of the control program, we select the type of results and complications to monitor. It may be the mortality rate, the rate of total wound infections, the rate of peritonitis in abdominal cases

etc. But the results to be collected must be defined as exactly as possible, based on the diagnostic procedures available.
2 – The vital function index: The physiological severity of each injury cas regarding respiration, circulation and brain damage.
3 – The anatomical injury: Grouping of each local injury in body regions, and degree of tissue damage.

We will first discuss these three factors, then illustrate with examples how a control program can be run:

1 – Definitions of results and complications

Eg. the Afghan quality control program: p. 703.

We list proposals on how to define results that may be useful for monitoring o the overall management quality. You may continuously register all of these complications in your clinic, or select a few. The list is not comprehensive; yo may add definitions of complications for special control programs: eg. systolic BP under 90 mm Hg on clinic admission – to monitor the effect of forward volume therapy. Or the rate of reoperations within one week after primary surgery – to control the quality of the primary surgery done. Or include laboratory indicators if such service is available.

- Mortality:
  - Dying within one hour after the injury: Cases dying from injuries so severe that probably the best forward management could not save them.
  - Dying within one day (24 hours) after the injury: A group of patients who might possibly have survived if the forward basic life support and surgery had been better.
  - Dying within one week after the injury: The group includes patients dying from early post-operative complications such as wound infections, peritonitis, post-operative pneumonia, septicemia. They might possibly have survived if the forward BLS and primary surgery had been better.
  - Dying within one month after the injury: The group includes patients with late post-operative complications such as multi-organ failure. They might possibly have survived if the primary surgery and post-operative care had been better.

- Wound infection – one of the following signs:
  - Local inflammation
  - Local pus
  - Local gas production

- Pneumonia – two of the following signs:
  - Fever
  - Productive coughing
  - New densities on chest X-ray

- Peritonitis – three of the following signs:
  - Fever
  - Abdominal tenderness
  - Abdominal withdrawal pain

- Abdominal wall rigidity
- Poor or absent bowel sounds

- Septicemia – three of the following signs:
  - Temperature over 39 degr.C
  - Local wound infection or abscess
  - Increased respiratory rate
  - Warm and dry limbs
  - Cardiac pump failure with circulatory shock
  - Bacterial growth in blood culture

- Adult respiratory distress syndrome (ARDS) – four of the following signs:
  - Major injury or surgery
  - Increased respiratory rate
  - Hypoxemia
  - New patchy densities on chest X-ray
  - No signs of cardiac pump failure

- Renal failure – two of the following signs:
  - Prior major non-renal injury or surgery
  - Urine production less than 0.5 ml/kg/hour that does not respond to volume therapy
  - Increasing serum creatinine

- Cardiac failure – all following signs:
  - Major non-cardiac injury or surgery
  - Lung congestion
  - Systolic blood pressure under 90 mm Hg without hypovolemia

- Disseminated intravascular coagulation (DIC):
  - Prior major injury or surgery
  - Increased general tendency to bleed
  - Reduced clotting time (clotting test)
  - Platelet count under 100 × 10 cells/l
  - No hypothermia

- Liver failure – both following signs:
  - Major non-hepatic injury or surgery
  - Clinical jaundice

- Multi-organ failure – both following signs:
  - Major injury or surgery
  - Failure of two or more organ systems

2 – Vital Function Index

The rate of complications must be assessed against the severity of the injury, that is, against the loss of vital functions, regardless of the localization of the injury/injuries. Any clinic should be able to save and rehabilitate a patient whose vital functions are good and stable after the injury. But it indicates high-

The Injury Chart: p. 52.

quality management to reach low mortality rates on patients with poor vital signs after the injury. Two standard injury score systems are used internationally to estimate the **physiological severity** of injuries – the Trauma Score and the Glascow Coma Scale. We recommend a simplified version of the two to be able to collect information on the vital functions directly from the standard Injury Chart. The vital function values are graded on a scale from 0 to 4, and summed up:

Vital Function Index

Clinical sign	**registered**	**grade**	**score**
Respiratory rate/minute	10-24	4	
	25-35	3	
	over 35	2	
	1-9	1	
	no respiration	0	?
Systolic blood pressure	over 90	4	
	70-90	3	
	50-69	2	
	under 50	1	
	no carotid pulse beat	0	?
Mental response	normal	4	
	confused	3	
	to sound	2	
	to pain only	1	
	none	0	?
			Sum up the points to get the Vital Function Index for each patient

On this scale a patient in stable state has a vital index score of 11 or 12. In other words, most clinics should be able to save patients with a vital index score of 8 to 10. And strive to save patients with vital index scores as low as 5 to 6.

Objections to the original Trauma Score

Two signs – respiratory effort and capillary refill – are included in the original Trauma Score. We exclude these signs because it is difficult to assess in a field setting at night, whether accessory muscles are used for breathing. And the predictive value of poor capillary circulation is uncertain: Cool and clammy skin may indicate pain as much as it indicates blood loss. Only the positive capillary sign, a warm and dry skin, has value indicating there is no major blood loss, and can help predict the outcome of that patient. Besides, it is difficult at night and outdoors, to read whether capillary refill is delayed more than two seconds.

The Glascow Coma Scale (GCS)
The GCS describes the degree of coma in skull injuries. It is useful in monitoring of individual skull/brain cases. It can also be used instead of the "mental response" section in our Vital Function Index (above). The GCS registers three signs – the patient's response with eye opening, speech and voluntary movements to a set of stimuli:

clinical sign	stimulus	grade	score
Eye opening	spontaneous	4	
	to voice	3	
	to pain	2	
	none	1	?
Speech	oriented	5	
	confused	4	
	inappropriate words	3	
	incomprehensible sounds	2	
	none	1	?
Movements	obey command	6	
	localize pain	5	
	withdrawal on pain	4	
	flexion on pain	3	
	extension on pain	2	
	none	1	?
			Sum up the points to get the GCS score for each patient

To include the GCS score into the Vital Function Index for quality control reasons, the GCS points should be graded:

GCS score 14-15	gives 5 points
11-13	4 points
8-10	3 points
5-7	2 points
3-4	1 point

3 – Classification of the anatomical injury

The Injury Severity Score (ISS) is based on values given to specific regional injuries by the Abbreviated Injury Scale (AIS). AIS is published by Association for the Advancement of Automotive Medicine, 2340 Des Plaines River Road, Des Plaines, Il 60018, USA.

Problems with the existing programs
Special programs are made to classify injuries regarding anatomical localization and severity, to predict risks of complications in relation to the severity of regional injuries. The AIS-ISS is one widely used program. There are three problems with the AIS-ISS program for wartime field use: One – the program is retrospective, based on elaborate coding of exact discharge diagnosis. That may be difficult to perform even in a major stationary civilian hospital, and impossible in a decentralized forward clinic system where patients are often dis-

charged/evacuated for reasons of security as soon as primary surgery is done. We need a program based on admission diagnosis. Two – the coding is too elaborate, and time consuming. Three – the AIS-ISS is developed for blunt injuries (one external trauma), to classify multi-penetrating injury cases (several separate projectiles with different energy content and energy output) commonly seen in wartime casualties is another and much more complicated matter.

Recommendation: Group the injuries in eight body regions
- Head and neck
- Face (no skull/brain injury)
- Spine
- Chest
- Abdominal and/or pelvic contents
- Limbs and/or pelvic girdle
- External (not penetrating the pleura, peritoneum or muscle fascia)
- Multi-injury: two or more high-energy/serious or very high-energy/critical injuries in one patient (see below)

Recommendation: Group the injuries regarding severity based on the first surgical exploration

Controlled experiments on animals indicate that the amount (grams) of tissue removed from the wound track by an experienced war surgeon at triage corresponds well with the energy output of the actual bullet as calculated physically.

"Severity" in this context means the degree of local tissue destruction, not the effect on body physiology. The degree of tissue destruction is partly predicted by the weapon history: type of projectile and range of the shot/explosion. But the exact severity of local injuries is determined by the projectile retardation inside the tissues, the energy output, which can only be classified during surgery. We recommend that the regional injuries are grouped in three main severity groups. The grouping is rough and must be so, given the vast spectrum of injuries produced by modern weapons:
- **Low energy – moderate:** The tissue destruction and the debridement are moderate. Include in this group burns of less than 20% TBSA.
- **High energy – serious:** The tissue destruction is extensive, the debridement is extensive, the organ/structures are seriously damaged. Include in this group burns of 20-40% TBSA.
- **Very high energy – critical:** The tissue destruction is critical for the organ/structure to survive, the debridement is very extensive. Include in this group burns of more than 40% TBSA.

Training courses for medical staff: p. 10.

In our system this grouping is done three times: First – by the field officer based on a weapon history and a brief clinical examination, and noted in the Injury Chart: p. 52. Second – in the clinic before surgery by an experienced doctor, and revised in the Injury Chart. Third – by the operating surgeon at the end of primary surgery and noted in the Patient Chart: p. 53. The correct grouping is obviously done by the surgeon. The grouping done before surgery, when compared to the surgeon's exact diagnosis, is useful to train forward staff in clinical assessment of injury cases.

Examples of quality control programs

The quality of forward basic life support

A forward clinic system (MMC in Afghanistan) has monitored the one-week, after-injury-mortality rate on all wartime casualties with Vital Sign Index of 8 or less when first seen by a paramedic, a total of 550 cases over four years. The first year the one-week mortality was 35%. The forward basic life support was improved to include insertion of chest tube, abdominal packing, venous cut-down, and limb fasciotomies. As a result the one-week mortality fell to 18%.

The organization of MMC at Jalalabad: p. 28.

The quality of the evacuation

The MMC clinics compared the registered vital signs in the field with the values registered at clinic admission, after a mean of five hours off-road evacuation. And found that 15% of the cases with BP over 90 mm Hg had dropped below 90 during the evacuation, and 30% of the cases with BP 90-70 had dropped below 70 mm Hg. As a result, the volume therapy during the evacuation was intensified, and forward abdominal packing was introduced as field basic life support routine in abdominal bleeding cases. Also the respiratory rate before and after evacuation was studied: One found increased respiratory rate in non-chest injuries during the evacuation indicating insufficient analgesia.That made MMC introduce low-dose i.v. ketamine as standard field analgesia to serious and critical injuries.

The effect of certain procedures

The MMC clinics also studied the effect on post-operative wound infections when fasciotomy was done at the site of injury on all high or very high-energy mine amputations. The mean time from injury to clinic surgery was five hours. The rate of wound infections fell from above 30% to 15% when early fasciotomy was done, the primary clinic surgery being the same. 90% of the patients included in this study had Vital Sign Index of 10 or better. Thus the main reason for the improved results was considered to be better local circulation effected by the fasciotomy.

Appendix 2

Blood-grouping, cross-matching and blood-banking

Blood-grouping

Emergency blood transfusion: p. 267.

Blood given to a patient is a foreign substance, and may cause transfusion reaction: Antibodies in the patient are activated when foreign blood antigens are introduced – some antibodies immediately, others after one or several contacts with foreign blood. The most important blood antigen-antibody body system of the immediate kind is the **ABO system.** The most powerful system of the delayed kind is the **Rhesus system.**

The ABO system

There are four different blood groups in the ABO system. Each person has only one of the four:
- Blood type A
- Blood type B
- Blood type AB
- Blood type O

To prevent transfusion reaction:
- Patients of blood type A should have A blood or O blood
- Patients of blood type B should have B blood or O blood
- Patients of blood type AB should have AB blood or O blood
- Patients of blood type O must have O blood
- In an emergency when you don't know which ABO group the patient has, give type O blood until the blood-grouping is done

The Rhesus system

Each person has antigens of either Rhesus D+ or Rhesus D– type.

When to blood-type? When to cross-match?

Test for both ABO group as well as D antigen before routine transfusions. Also do a cross-matching (see below) in case the patient has developed other anti-

Monitor closely for transfusion reactions when O blood is used without typing and cross-matching: p. 269.

bodies. In emergencies, blood transfusion starts immediately with O blood, and the patient should be grouped for ABO as soon as possible to shift to gro correct transfusions. If O blood is not available, you may transfuse blood afte simple cross-match if you consider immediate transfusion to be life saving. Rhesus testing is generally not necessary in emergencies. But before elective surgery, especially in fertile women, the Rhesus D group should also be deter mined.

Equipment for ABO grouping, Rhesus D grouping, and simple cross-matching

Blood centrifuge
Magnifying mirror
Pipette (Pasteur or similar)
Test tubes, 3 and 10 ml
Glass or plastic plates
Wooden sticks
NaCl 0.9%
Anti-A antibody solution
Anti-B antibody solution
Albumin agglutinating anti-D antibody solution

How to do the ABO grouping

Put 10 ml blood from the patient in a tube. Centrifuge for five minutes at speed of 3000 rounds per minute (rpm) to separate the serum and the cells. Use the pipette to transfer the serum to a separate tube, mark the tube with the patient's name. Now you have two tubes – one with the cell concentrate, and one with the serum. The grouping can start. Put on the glass plate:

- **On spot 1:** two drops of anti-A antibody solution, add patient's cells with a stick
- **On spot 2:** two drops of anti-B antibody solution, add patient's cells with a stick
- Always store some blood samples of known A and B cells for better security i you do blood-matching on a larger scale. In that case:
- **On spot 3:** two drops of patient's serum, add known A+ blood cells with a stick
- **On spot 4:** two drops of patient's serum, add known B+ blood cells with a stick

Look for **sedimentation on the test spots** to read the blood types: Antigens on the A cells will react with antibodies against A cells to form particles that you can see with the magnifying mirror. That reaction is called sedimentation. Sedimentation on a test spot always indicates that an antigen (A, B, or AB) **and** the antibody against that antigen (anti-A or anti-B) are **both** present on that test spot:

- **If the patient has blood group A, spots 1 and 4 will sediment:** On spot 1 the anti-A antibody solution reacts against the A cells. On spot 4 the A serum reacts against the known B cells.
- **If the patient has blood group B, spots 2 and 3 will sediment:** On spot 2 the anti-B antibody solution reacts against the B cells. On spot 3 the B serum reacts against the known A cells.

- **If the patient has blood group AB, spots 1 and 2 will sediment:** On spot 1 the anti-A antibody solution reacts against the AB cells. On spot 2 the anti-B antibody solution also reacts against the AB cells.
- **If the patient has blood group O, spots 3 and 4 will sediment:** The patient's serum contains anti-A and anti-B antibodies that react against the known A and B cells.

How to do the Rhesus D grouping

- Put one drop of albumin agglutinating anti-D solution in a test tube
- Add blood cells from the patient's cell concentrate with a stick
- Set the mixture aside for five minutes in 20-25 degr.C
- Shake the tube, then spin it in the centrifuge for 1 minute at 3000 rpm
- Look for sedimentation with the magnifying mirror: Sedimentation indicates Rhesus D+ group, no sedimentation indicates Rhesus D– group
- Notice: The test is more accurate if you simultaneously mix the anti-D antibody solution with a control D– blood sample that you know will not sediment, and compare the patient tube with that control tube

Cross-matching

It is to test if the patient's blood reacts against the donor blood you plan to use for transfusion. Simple cross-matching is to test the actual donor blood cells against the patient serum.

How to do simple cross-matching

- Put two drops of NaCl 0.9% in a test tube.
- Make a blood cell concentrate of the donor blood (see above), dip a stick in the blood cell concentrate, and mix the donor cells with the saline.
- Wash the mixture by filling the tube with saline, and spin it in the centrifuge for one minute at 3000 rpm. Remove the saline with pipette.
- Add two drops of patient's serum to the washed donor blood cells.
- Set the donor-patient mixture aside for five minutes in 20-25 degr.C.
- Spin the mixture in the centrifuge for one minute at 3000 rpm.
- Read the sedimentation with magnifying mirrors: No sedimentation indicates that the donor blood may be used for transfusion. Sedimentation indicates that antibody-antigen reaction of some sort has happened, and the donor blood should not be used for that patient.

Blood-banking

Improvised direct blood transfusion: p. 270.

If the resources are few and the forward clinic mobile, we recommend a "walking blood bank" for field use: Blood-group the local population, soldiers and clinic staff. Take special care to identify a certain number of blood type O donors. Make blood group cards that the donors should always carry around their neck. Make a calling system so you can scramble donors rapidly in emergencies. The donors themselves will profit on being grouped in case they themselves become wounded.

Appendix 3

Microscopic examination of bacteria. The gram-stain procedure

Notice:
- The diagnosis "infection" is based on clinical signs. Close monitoring of wounds and general condition, not the microscope, is necessary to identify infections at an early stage.
- In many cases you do not need the microscope to point out the bacteria probably responsible for that infection: The look and smell of wounds and pus, and knowledge of common bacterial patterns of infections, will enable you to make a qualified guess.
- The gram-stain and microscopical examination can give valuable additional information. But it cannot replace clinical common sense.

Equipment necessary
- clean glass slides (25 mm × 75 mm)
- flame
- microscope
- immersion oil
- crystal violet solution: 2 g crystal violet per 100 ml ethanol 95%
- iodine solution: iodine 0.33 g, and potassium iodine 0.67 g, per 100 ml distilled water
- safranin solution: 0.25 g safranin per 100 ml ethanol 95%.

Collection of clinical materials for staining

Materials for staining may be pus, normally sterile body fluids, and infected tissue. There are some precautions:
- Choose the material most likely to show the actual infection. Eg. collect and stain real bronchial mucus to assess a pneumonia, not a throat swab.
- Avoid contamination of the material by other bacteria from the patient or staff.
- If possible, collect the material before the antibiotic therapy starts.

- Do not mix antiseptics with the material. Wash with soap-water, not potent antiseptics, before you do a diagnostic needle puncture of an abscess.

Preparation of the smear
- Wear gloves.
- A tissue sample: Roll swabs with the material with firm pressure over a small area on the glass slide.
- A thin fluid sample: Place one drop of the fluid in the center of the slide, let it dry without being spread.
- A thick, viscous sample: Place one drop of the material on the glass slide, cover it with a second slide. Press the slides together, and pull them apart.
- Air-dry the sample. Then heat-fix by passing the slide three times (about one second each) through a flame. The slide should be warm, but not hot. Cool the slide before staining.

The gram-stain procedure
- Flood the thin, air-dried, and heat-fixed glass slide smear with **crystal violet solution (dark blue)** for 30 seconds. Then wash gently under running water.
- Flood with **iodine solution (brown)** for 30 seconds. Wash gently under running water.
- Critical step: Remove excess color by letting **ethanol 95%** flow over the slide until the runoff becomes clear, or the thinnest parts of the smear are colorless.
- Counter-stain by flooding the slide with **safranin solution (red)** for 30 seconds. Wash gently under running water.
- Air-dry the smear. It is ready for microscopic examination.

The microscopic examination
Examine the smear under an oil immersion objective:
- Check if the smear really contains infectious material: Examine the smear under low power, look for inflammatory cells close to bacteria – a main sign of infection.
- Check the technical quality of the smear: Use the oil-immersion lens. The nuclei of inflammatory cells should stain red or purple. If the cell nucleus stains blue or the background is blue, the excess color has not been sufficiently removed (see "critical step" above).

Examine and try to type bacteria and cells

The form of bacteria
- coccus – round bacteria
- bacillus – rod-like bacteria
- coccobacillary – small rod-like, often varying in size

The color of bacteria
- gram-negative – red bacteria
- gram-positive – blue bacteria
- gram-variable – some red, some blue bacteria

Make a qualified guess

- gram-positive cocci in irregular clusters: staphylococcus
- gram-positive cocci in pairs and short chains: enterococcus/streptococcus
- large gram-positive bars (often gram-variable): clostridium/bacillus
- gram-negative bacilli: enterobacteria
- small gram-negative bacilli varying in size: haemophilus/bacteroides

Problems with the gram-stain smear

- The infectious material must contain about 100 000 bacteria per ml to make possible a microscopic diagnosis. You can hardly draw any conclusions if the number of bacteria is small, and no inflammatory cells are present.
- In acute infections, the smear usually contains one (or two) types of bacteria. But different types of bacteria may appear identical in the gram-stain procedure: Always compare the microscopical picture with the clinical facts, and with a gross examination of the infectious material.
- Gram-positive bacteria may appear rather gram-negative if they are old or treated with antibiotics.
- Draw conclusions with care, accuracy depending on training and skill: Artifacts, such as particles of crystal violet, may be misinterpreted as cocci or bacilli.
- You may have lost material from the smear during staining: The smear has been too thick, or the heat-fixation poor.
- You may check the gram-stain technique by staining your own sputum, which contains both gram-positive and negative bacteria, as well as epithelial cells.
- We recommend additional staining procedures for pus where no bacteria are observed (eg. acid-fast stain). See laboratory manuals: p. 717.

Appendix 4

Books recommended for further studies

War surgery

Trueta: The principles and practice of war surgery. CV Mosby Company. St. Louis, USA, 1943. An excellent introduction to war wound management in general, and management of limb injuries and missile fractures in particular.

Coupland: War wounds of limbs, surgical management. Butterworth-Heinemann Ltd. Oxford, Boston, New Delhi, Singapore, Sydney, 1993. A basic, up-to-date, practical guide.

Swan KG: Gunshot wounds. Year book med, 1989.

Swan, KG: Gunshot wounds, pathophysiology and management. Littleton. Massachusetts, USA. 1980. A useful introduction to the physiology of injury, but not up to date in weapon physics.

Dufour et al: Surgery for victims of war. International Committee of the Red Cross. Geneva, 1990. A brief and basic book on the special problems of surgery during war. Readable.

Central Sanitaire Suisse: Doctors' guide for catastrophes and wars. CSS, Postfach 145, 8031 Zurich, Switzerland. 1992. A brief pocket-size manual in injury and war casualty management written for Third World settings. Too brief to be used as teaching material. Instructive on chemical warfare injuries.

United States Department of Defense: Emergency war surgery. United States Government Printing Office. Washington DC, 1988. A brief handbook for the military doctor. Useful also for the experienced doctor who is not working in a regular army. The surgical procedures are not illustrated or explained in detail.

Kirby, Blackburn: Field surgery pocket book. Her Majesty's Stationary Office. London, 1983.

Heyndrickx: Biological and chemical warfare. State University of Ghent, Belgium, 1984. Scientific documentation on the use and effects of common chemical and biological weapons. Not very useful in the management of such injuries.

Injury surgery

American Heart Association: Guidelines for cardiopulmonary resuscitation and emergency cardiac care. JAMA, 1992; 268, No. 16. A brief, illustrated, and practical introduction to basic life support procedures essential also in war casualty management.

King: Primary surgery. Volume two: Trauma.
Oxford University Press. Oxford, New Delhi, Kuala Lumpur, 1987. A well-illustrated manual in injury surgery, written for minor district hospitals with moderate technical resources.

Mattox, Moore, Feliciano: Trauma. Appleton and Lange. Norwalk, Connecticut, 1988. A comprehensive and up-to-date textbook in injury management. A good investment if you are treating war casualties, but expensive.

Landon: Atlas of trauma management: The first hour. Encyclopedia of visual medicine. S. Parthenon publisher, 1993. Good illustrations in injury management. A useful book in the treatment of critically ill patients.

Rutherford et al: Accident and emergency medicine.Churchill Livingstone. London, 1989. A basic textbook in injury management, well written and up-to-date.

McNair: Hamilton Baily's Emergency surgery. John Wright and sons Ltd. Bristol, 1986. A basic book on emergency surgery. Not so detailed in operative technique, but comprehensive on the important surgical problems. For the more experienced surgeon.

Tinker, Rapin: Care of the critically ill patient. Springer Verlag. New York, Berlin, Heidelberg, 1983. A comprehensive textbook, useful for a hospital library.

General surgery

Zollinger and Zollinger: Atlas of surgical operations. McGraw-Hill. New York, 1993. An instructive atlas for the new surgeon. In a large format, it may be too heavy for field use.

Rintoul: Farquharson's Textbook of operative surgery. Churchill Livingstone. Edinburgh, London, New York, 1986. A brief introduction recommended for the junior surgeon, instructive in the basic operative techniques.

Sabiston: Textbook of surgery. The biological basis of modern surgical practice. WB Saunders Company, USA, 1991. A general book in surgery. Offers basic principles in a readable way.

Calne, Pollard: Operative surgery. Gower Medical Publishing, USA, 1991. A basic book in general surgery.

Rob, Smith: Operative surgery. Butterworths. London, 1992. A comprehensive work of 19 volumes that describes step by step the basic operations with illustrations. The complete work is expensive; selected volumes may be useful for a major hospital. We recommend especially the volume on thoracic surgery.

Abdominal surgery

Jones: Emergency abdominal surgery. Blackwell scientific publications. Oxford, London, Edinburgh, 1987. A smaller book on emergency surgery, handy for the war surgeon.

Seymour, Schwartz, Ellis: Maingot's Abdominal operations. Appleton-Century-Crofts. Norwalk, Connecticut, 1990. 2 volumes. A comprehensive book on abdominal surgical diseases and the treatment. Useful if you have to treat abdominal diseases in general. For studies and as manual in the small hospital.

Urology

Blandy: Lecture notes on urology. Blackwell scientific publications. Oxford, London, Edinburgh, 1989. A brief introduction to urology, sufficient for the injury surgeon.

Tanagho, McAninch: Smith's general urology. Appleton & Lange. Norwalk, Connecticut. A more comprehensive book on urology. Not necessary for injury management, but useful in the hospital dealing with general urologic problems as well.

Vascular surgery

Haimovici: Vascular surgery. Principles and techniques. Appleton & Lane. New York, 1989. A basic and comprehensive book on vascular surgery. Good explanations of technical details. Useful in the library if you have to treat vascular problems.

Orthopedics

Dandy: Essential orthopaedics and trauma. Churchill Livingstone. Edinburgh, London, Melbourne, New York, 1989. A useful book in the emergency setting.

McRae: Practical fracture treatment. Churchill Livingstone. London, 1989. A recommended book for field-work, readable with good illustrations.

Bunker, Cotton, Webb: Frontiers in fracture management. Martin Dunitz, UK, 1989. Contains important principles and advances in fracture treatment. Useful references.

Stewart, Hallet: Traction and orthopaedic appliances. Churchill Livingstone. Edinburgh, London, Melbourne, New York, 1983. A brief, practical and detailed guide to making and using traction, plaster casts, orthosis and walking aids.

Face surgery

Kruger, Schilly: Oral and maxillofacial traumatology, vol 1 and 2. Quintessence books, London, 1986.

Rowe NL, Williams JL: Maxillofacial injuries. Vol 1 and 2. Churchill Livingstone. London, 1989.

Eye injury

Friedberg, Rapuano: Office and emergency room diagnosis and treatment of eye disease. JB Lippincott Company, Philadelphia, 1990. A brief manual on the most important subjects.

Burns

Fang: Modern treatment of severe burns. Springer Verlag. New York, Berlin, Heidelberg, 1992.

Wardrope, Smith: Wound and burn management, Oxford Handbooks in Emergence Medicine vol 3. Oxford University Press, 1990. A handy book for emergency treatment.

Plastic surgery

McGregor: Fundamental techniques of plastic surgery – and their surgical applications. Churchill Livingstone, Edinburgh, London, Melbourne, New York, 1989. A short, instructive, and basic book on plastic surgery.

Nutrition

Whitney, Hamilton: Understanding nutrition. West Publishing Company. Minnesota, USA, 1984. An instructive, comprehensive, and readable introduction to basic nutrition.

Krause, Mahani: Food, nutrition and diet therapy. Saunders. USA, 1984. Shils and Young: Modern nutrition in health and disease. Lea and Fabiger. USA, 1988. Both books are comprehensive on nutrition and malnutrition.

Tropical medicine

Gowan, Heap: Clinical tropical medicine. Chapman and Hall. London, 1993. A short textbook in tropical medicine.

Manson-Bahr, Apted: Manson's tropical diseases. Bailliere Tindall. London, 1982. A comprehensive textbook.

Pediatrics

Jeliffe, Stanfield: Diseases of children in the subtropics and tropics. Edward Arnold (Publishers) Ltd. London, 1986. A comprehensive textbook, very instructive in clinical diagnosis of common endemic diseases.

Cameron, Hofvander: Manual on feeding infants and young children. Oxford University Press. New Delhi, Nairobi, 1983. A guide to malnutrition management, practical nutritional procedures, and local food processing.

Laboratory medicine

World Health Organization (WHO): Basic laboratory procedures in clinical bacteriology. WHO. Geneva, 1991.

Anesthesia

Dobson: Anaesthesia at the district hospital. World Health Organization, 1988 Jaypee Brothers. New Delhi, 1989. A well-illustrated and instructive introduction to ABC management, general and local anesthesia, and diseases that may complicate anesthesia.

Aitkenhead, Smith: Textbook of anaesthesia. Churchill Livingstone. Edinburgh, London, Melbourne, New York, 1990. A not too heavy book with good illustrations on regional and general anesthesia.

Brown: Atlas of regional anaesthesia. Saunders. USA, 1991. An illustrated book in regional nerve blocks.

Staff training

Werner, Bower: Helping health workers learn. Hesperian Foundation. Palo Alto, USA, 1992. A basic and instructive book, recommended for everybody engaged in medical staff training.

Acknowledgements

The authors are specially indebted to Hanna H. Hansen; Assadullah Reha, MD, Director of Mujahed Emergency Medical Center (MMC), Jalalabad, Afghanistan; the staff of MMC, Jalalabad; the honored members of the Jalalabad Shura; Commander Qari Baba, Governor of Ghazni Province, Afghanistan; Sann Aung, MD, Minister of Health, NCGUB, Burma; the students of the NCGUB War Casualty Managment Training Course; HM Singh, MD, former Consultant Surgeon, Karen Base Hospital, Burma; Mads Gilbert, MD, Section Head Emergency, Department of Anaesthesia, Tromsoe University Hospital; Chris Giannou, MD, former Consultant Surgeon, Palestinian Red Crescent Society. We should also have acknowledged some other fellow doctors caring for the wounded but conditions prevent us from mentioning their names. Without the interest and patience from these friends, we would not have been able to develop and test the teaching material for training in forward wartime surgery, from which this manual is derived.

We thank the following persons for their assistance, advice, and encouragement:

V Arnulf MD
S Bergstr¢m MD
LJ Garvik
K Gargesh MD
PA Gulowsen MD
KI Hansen
B Heger MD
E Hem MD
F Jerve MD
F Khoo
H Kuloey
J Pilgram-Larsen MD
IM Pinder MD
T Lund MD
A Lyslo MD
M Mikkelsen
B Nicolaissen MD
PT Nilsen
HK Nordby MD
U Pedersen
L Salemark MD
A Skagseth MD
P Skjelbred MD
SRS Smith MD
K Solheim MD
PA Steen MD
J Stevens MD
KE Stroemskag MD
K Stroemsoe MD
PO Sundnes MD

A Sundsfjord MD
N Soerheim MD
TW Wadsworth MD
JA Weigelt MD
D Werner
P Worlock MD
O Ugland MD

The production of this publication was sponsored by the Asmund Laerdal Foundation for Acute Medicine Inc, Norwegian Air Ambulance, and the Norwegian Ministry of Foreign Affairs. We also acknowledge contributions from Norwegian Board of Health, Norwegian Church Aid, Norwegian People's Aid, Save the Children Norway, AS Apotekernes Fellesinnkjoep Oslo, Norwegian Aid Committee, and Norwegian Non-fiction Writers' and Translators' Association.

Glossary

Listed here are medical terms commonly used. Words in **bold** are all listed as separate entries in the glossary. If you cannot find some terms in the glossary, look them up in the Index, they may be explained or illustrated in the text.

A

abdomen the cavity in the body trunk between the **diaphragm** and the **pelvis,** above the diaphragm is the chest

abdominal cavity that part of the abdominal cavity which is inside the **peritoneal** lining. This lining divides the abdominal cavity into the abdomen proper, and outside the lining is the true **pelvis**

abduction moving a limb away from the central (midline) line of the body

abortion expulsion, or removal of the early contents of pregnant womb. A miscarriage is a natural abortion, while abortion can also be achieved by scraping out the pregnant womb

abscess a cavity or space filled with pus

absorb to suck up, take into

absorbable (sutures) material which when placed in the body will "dissolve" in the body with time. Thus absorbable stitches do not need to be removed. Catgut, Dexon, and Vicryl are examples of suture materials which are absorbed by the body tissue

accelerate to increase in speed

Achilles tendon the strong heel tendon by which the calf muscles flex the ankle joint

acidosis too much acid in the blood. The degree of acidosis is measured in units of pH. Normally the blood pH is between 7.2 to 7.4. The pH may vary as stress or exhaustion increases the production of acid. Or the acid production may be normal, but the body is unable to get rid of the acid because the kidneys or the lungs are not working properly

acromion the point of the shoulder blade

acute sudden

adduction to bring a limb or digit towards the midline

adhesion early or late scar tissue that makes the body linings and organs stick to each other. In the abdomen, adhesions may form between intestines and **peritoneum.** In the joints, adhesions may form between the lining of the joints, between tendons and the surrounding soft tissues

adventitia outside layer of the intestines, blood vessels, and nerves. Adventitia consists mainly of loose **fibrous** tissue

aerobic infection infection by bacteria which flourish in the presence of oxygen. Also see **anaerobic infection**

airway the whole air passage from the nostrils to the lung tissue. It consists of the nostrils, nasal cavity, the **pharynx, larynx, the trachea, bronchus,** small bronchial branches and the air sacs

albumin a protein found in the blood, which is important for keeping the water molecules inside the circulating blood volume through osmotic pressure. Loss of albumin results in water being drained from the circulating blood to the tissues, which then swell **(edema)**

allergy/allergic the body's way of over-reacting to certain substances. It can be mild like a local skin rash (skin allergy), hay fever (the upper airways reacting to substances in the air), or severe when the blood forms allergic complexes to drugs like penicillin, or a different type of blood.

allograft tissue **graft** from another person, like skin graft or bone graft. The commonest allograft is blood transfusion

alloplasty/allplastic surgery with synthetic **graft**

alveolus/alveolar alveolus is the terminal part of the airway where the branching small **bronchi** end in sacs. These sacs are very rich in blood supply, and being thin-walled, allow the blood to come into contact with the breathed-in air. The blood takes up oxygen, and at the same time **carbon dioxide** is given out into the sacs and is breathed out

ambulation to make mobile, eg. to get out of bed, to walk, to move with a wheelchair

ameba a single-cell parasite which invades the large intestine and feeds on red blood cells

amino acid the molecule units which make up proteins

amniotic fluid the fluid which surrounds the **fetus**

anabolism absorbing food and building up body stores of **carbohydrate,** protein and fat

anaerobic infection infection by bacteria which grow in conditions with little or no oxygen

analgesia "without pain", to remove or decrease pain with the use of drugs and injections

analgesic painkiller, it may be simple, like aspirin tablets, or complicated like intercostal nerve blocks and ketamine **anesthesia**

anastomosis a joining of two tube ends together surgically

anemia low **hemoglobin** of less than 10 g/100 ml

anesthesia, local local injections of substances which abolish all sensations, making an area "numb"

anesthesia, general injection or breathing of **anesthetics** which knock off the brain centers temporarily so that a state of unconsciousness and unawareness results

anesthesiology the science of effecting and reversing anesthesia

anesthetic substances which produce anesthesia

antacid alkaline substances taken to neutralize the acid fluids in the stomach

anterior to the front

antibody a protein produced by the body to neutralize "unfriendly" agents, like bacteria, viruses, **toxins.** Some-

times the body makes a mistake and starts producing antibodies to common substances like food, pollens, and **allergy** results, or to its own tissues – auto-antibodies

antidepressant drug drugs which elevate mood, and therefore help counter psychological depression

antihistamine histamine is a substance important in bringing about an **allergic** reaction, antihistamine is a drug to block the action of histamine

antiseptic "against **sepsis**" – substances which kill bacteria and other organisms which cause infections

anuria not producing urine; real anuria indicates the kidneys have packed up, but most clinical anuria is due to the urinary outflow being blocked – for instance, a blocked catheter

anus/anal the end of, normally refers to the bottom end of the intestinal canal, where the **rectum** meets the outside

aorta/aortic the main blood vessel of the body. It leaves the heart with fresh blood and runs upwards curving down to descend into the chest and abdomen where it finally divides into the two main arteries for the lower limbs. All along the way, it gives out branches to various organs like the heart muscle, the lungs, the liver, the neck, the kidney, the intestines, and the limbs

arrhythmia "wrong rhythm" – referring to the heart rhythm being abnormal in speed and regularity

arteriography an X-ray technique to outline the arteries by injecting dye (contrast) into them

arteriotomy to make an opening into an artery

arthritis joint inflammation which may be caused by infection, chemicals, injury, or wear and tear

arthrodesis joint fusion: The joint cartilage is removed, and the bone ends compressed together, the resulting bony union thus abolishes all joint movement

arthroplasty surgical creation of a new joint: This can be done by resecting the old deformed joint and allowing the remaining bone ends to move freely between soft tissues, eg. a resection arthroplasty like the Girdlestone hip arthroplasty. Alternatively, replacemement arthroplasty is where a synthetic joint is inserted into the bone ends replacing the old joint

ascend to go up, to increase

aspiration/aspirate to draw up, also refers to the backflow or vomiting of stomach contents and then breathing them into the lungs

atelectasis collapse of lung tissue

atrium/atrial the chambers of the heart which receive blood from the veins: Thus the right atrium receives venous blood from the **caval vein,** and the left atrium receives blood from the lung veins

auscultation to listen with a stethoscope

autotransfusion transfusion with own blood

autoclave a machine, not unlike a sophisticated oven, where bacteria and disease-producing organisms are destroyed by heat, either moist or dry heat

autonomic nervous system part of the nervous system that functions without the control of our will. It regulates the functions of internal organs as well as circulation, breathing, **metabolism.** See also **vagus nerve**

axilla the armpit

B

biceps the muscle on the front of the arm which flexes the elbow. Also one of the muscles **(hamstrings)** on the backside of the thigh which flexes the knee

bile/biliary yellowish-green, bitter digestive juice secreted by the liver, and stored in a pouch called the gall bladder

biologic living

biomechanics the study of the mechanics of skeletal motion in living things

blood gas the oxygen and **carbon dioxide** carried in the blood

blood smear (diagnostic) spreading blood on a glass slide and staining it so that details can be examined under a microscope

blunt (injury) injury caused by blunt agents (as opposed to **penetrating injury**). Blunt injuries typically involve ill-defined, large areas which are crushed, deep and with internal bleeding

bolus ball, thus food bolus, bolus injection is a one-shot dose as opposed to continuous infusion

BP blood pressure

brachial arm

bradycardia slow heartbeat

brain stem the lower part of the brain, joining the top or forebrain to the **spinal cord.** It is the most important part of the brain controlling vital functions like breathing, heart, temperature

broad-spectrum (antibiotic) effective against a large spectrum, or many types of bacteria

bronchus/bronchial the branches (or bronchi) arising from the **trachea**

bulb of eye eyeball

C

C (centigrade) when measuring temperature, the Centigrade scale is divided into 100 units or degrees – 0 being

the freezing point of water, and 100 being the boiling point of water, the human body temperature is 37 degrees Centigrade

C (cervical) neck, C1 means the first cervical **vertebra** or segment, C2 the second and so on

cadiac output the volume of blood pumped out by the left side of the heart (left **ventricle**) into the **aorta** every minute. It is the volume of blood rich in oxygen that the heart sends to all parts of the body every minute

cal calorie, a unit for measuring heat, where one calorie raises the temperature of one gram of water by one degree Centigrade

calcaneus the heel bone

callus soft new bone, which is formed during the early part of fracture healing

calorie, see cal

cancellous (bone) spongy bone rich in marrow and blood supply. The **vertebral bodies,** the ends of long bones are all cancellous

cannula a tube for inserting into blood vessels or body ducts and tubes, so that infusions and drugs could be given

capillary the terminal branch of the artery and vein. It is small with thin walls so that **blood gases** and nutrients could be exchanged between the tissues and the blood, and in the case of the lung **alveoli,** between the atmosphere and the body

carbohydrate chemical substances containing carbon, hydrogen and oxygen, the unit of which is the sugar molecule, such as starch or glycogen

carbon element which commonly exists as coal, or rarely as diamond. It is the basic element of organic compounds from which living things are made

carbon dioxide when carbon is burnt in oxygen (air), the molecules of carbon and oxygen join to form carbon dioxide. To produce **energy,** the body slowly burns **carbohydrate,** which forms carbon dioxide that is carried to the lungs and out to the air

cardiac heart

carotid the main arteries to the head and neck

catabolism breaking down of body tissues resulting in weight loss and wasting

catheter a hollow tube which can be inserted into the bladder to drain urine out, through the nose into the stomach to drain gas and fluid, into the blood vessels to give infusions and drugs, or used as a drain for a **hematoma**

cautery burning, used mainly to burn small vessels during surgery so that bleeding stops

caval vein the main vein of the body which carries used blood back into the heart so that the blood low in oxygen and high in **carbon dioxide** could be directed to the lungs to be reoxygenated and decarbonized

cavitation to form a cavity

cecum the beginning of the large intestine

cellulitis local inflammation due to infection without well-defined boundaries in subcutaneous and connective tissue

cereal seeds of the grass family; common cereals are barley, rice and wheat

cerebrum the forebrain, which is responsible for higher intellectual functions and memory

cervical neck

cervix of uterus the junction of the vagina and uterus

cholecystectomy removing the gall bladder

choledochus bile duct

chronic long-term

circulation an overall term describing the function of the blood, heart and vessels

citrate salt form from citric acid, which is in citrus fruits

clavicle collar bone

cm (centimeter) one hundredth of a meter

coagulation blood clotting

coccyx the tail end of the **spinal** column; in animals it is the tail bones. In humans, the coccyx is very small and lies buried in the natal cleft

collagen a protein of **connective tissue** that forms strong fibers as in tendons

collateral (vessel) parallel blood vessels

colon large intestine

coma a state of unconsciousness

comatose to be in coma

comminuted fracture broken bone, where there are more than two fracture fragments

compound (fracture) open fracture, where the skin is breached and the fracture communicates with the outside environment. This means bacteria from the outside can get into the bone and infect the fracture

consciousness wakefulness

condyle "knuckle", an expanded end of a bone

congestion over-accumulation of fluid, eg., blood in the lungs, heart, liver, legs

congestive heart failure the heart failing as a pump. There is backlog of fluid, since fluid is not pumped on

conjunctiva the lining of the exposed part of the eyeball, and the inner side of the eyelid

connective tissue usually consists of fiber cells, muscle cells, fat cells and collagen bundles

conservative a preserving attitude. When a **debridement** is described as conservative, it means to save as much tissue as possible. The opposite is radical, meaning to get rid of as much as possible

contamination the presence of bacteria or infectious substances
contracture describes a state where the joint capsule and **ligaments** are permanently shortened (contracted) thus limiting full movements of the joint
convulsion fits
cord (spinal) the large nerve tube running in the **spinal** canal
cornea the clear lining of the eye over the pupil
coronary vessels the blood vessels supplying the heart muscle
corrugated (drain) drains made from flat, wavy rubber
cortical (bone) strong, dense laminated bone – such as the shaft of long bones
costa/costal rib
counter-traction opposing pull against primary traction
counter-incision additional incisions which will help in the exploration
crepitation fine bubbling of the lungs due to the **alveolar sac** being filled with fluid
cricoid the "Adam's apple"
cross-match technique used to identify blood that may be used for transfusion
curettage scraping with a curet – a surgical spoon
cutis/cutaneous the visible part of the skin
cyanosis when blood loses much of its oxygen, it becomes dark and loses its red color, and this gives a bluish, purplish color when seen through the transparent structures like the nails, the under-surface of the tongue, the conjunctiva.
cyst a fluid-filled sac lined by a body membrane
cystography X-ray technique of visualizing a cyst by filling it with contrast media, eg. X-ray examination of the urine bladder

D

debridement removing debris. It refers to the surgical technique of cutting away damaged and dead tissue and mechanically removing dirt particles from a wound
debris dirt, rubbish and foreign fragments
decompression to reduce pressure. It can be done by draining fluid and gas by naso-gastric tube. Or by removing a constricting roof, tunnel as in **fasciotomy** where pressure is released by splitting the roof of the tight canal formed by fascia and bone. Or in spinal decompression, where the bony ring of the vertebra is deroofed to reduce the pressure on the spinal cord, also see **laminectomy**
decortication removing the outer layer of. To remove the roof of a **pleural abscess,** or one cortex of a **osteomyelitic bone.** Decortication opens up an infected cavity and allows free drainage of pus
dehydration reduction of the water content of the body, as when losses by diarrhea are not compensated for by drinking more fluid
dental teeth
dependent drainage to drain (fluids) by gravity
dermatome an area, segment of skin supplied by one **spinal** nerve root
dermis/dermal the deep layer of the skin
diabetes excessive output of urine. Diabetes mellitus is a condition with hyperglycemia and excessive output of sweet urine
diaphragm the transverse dome-shaped muscular layer which separates the chest from the abdomen; the diaphragm is also the main muscle for breathing
diastolic relating to the relaxation of the heart **ventricles**
digitalization to treat with digitalis, which is a drug increasing the force of heart muscle contraction
dilation increase in circumference and size, to stretch
disarticulation to remove through a joint
disinfect to kill bacteria and micro-organisms by chemicals, heat or radiation
disinfectant substance which disinfects
dislocation joint surfaces becoming dissociated, out of joint
displacement refers to fractures when the two ends are shifted in relation to each other
dissect to cut up surgically
dissection, sharp to surgically cut using a sharp technique, classically with a scalpel
dissection, blunt to open up tissue surgically using a blunt or round instrument, such as the finger tip, a gauze swab
distal away from the head
distraction (of fracture fragments) to pull apart
distress, respiratory breathing difficulty from mechanical problems like fractured ribs, **pneumothorax**
distress, fetal the unborn child in distress in the womb, usually due to lack of oxygen; this shows up as slowing down of the fetal heart rate
diuretic substance to increase the production of urine
diversion stoma interrupting the flow of intestinal content by diverting it outside through the abdominal wall. This is usually done by making an opening in the intestine – stoma – proximal to an injury to let the **fecal** stream drain out through the abdominal wall
donor the area or the person from whom **grafts** are taken
dorsal the back

duct a hollow body tube conveying fluid, juices
duodenum the first 12 inches of the small intestine
dura/dural the sac which lines the brain
dynamic permitting movements and flexibility

E

ECG electrocardiograph, tracing of the electrical activity which takes place in each cardiac cycle
-ectomy surgical removal, eg. nephrectomy – removal of one kidney
edema diffuse swelling due to accumulation of tissue fluid
electro-cautery to burn with electricity
electrolyte substance which when disssolved in water produces charged particles. Salts and elements in the blood and body tissue are electrolytes unless they are chemically attached to other substances
elevation to raise up. When referred to a limb, it is to raise it up beyond the heart level
embolectomy remove an embolus, blood clot by arteriotomy or specially designed embolectomy catheters
embolism the process of throwing up blood clots, clumps of bacteria, air, tumor into distant blood vessels
embolus/emboli blood-borne particles, such as, clots formed inside the bloodstream, particles of tumor, bacteria etc.. which break lose and travel with the blood to other parts of the vascular tree, see also **thrombus**
emphysema a lung disease characterized by partial small and medium airway obstructions resulting in the lungs being over-expanded, with diminished gas exchange, and the adjacent walls of the **alveoli** breaking down
empyema pus in the **pleural cavity**
endemic local, coming from within the community
endocrine glands without ducts, secreting **hormones** directly into the blood
endotracheal (intubation) into the **trachea** – endotracheal intubation is to put a non-collapsible tube into the trachea so that oxygen can freely enter the lungs
energy the work or force within a system
enteral the stomach and intestines
enteritis inflammation of the intestines through infection, **allergic** reactions, damage
enterostomy a stoma, opening of the intestine leading to the outside for either diverting the intestinal contents from the distal intestine, or for introducing nutrients into the proximal intestine for feeding purposes
enucleation removal of a round structure, such as taking out the eye
enzyme a biological substance that speeds up a chemical reaction
epicondyle (of humerus) the enlarged distal ends of the **humerus** where the muscles of the forearm find origin
epidural the space inside the **spinal** canal and skull superficial to the **dural** sac
epigastrium overlying stomach area
epineurium the outer covering of a nerve
epiphysis the growing cartilage at the ends of a bone in children, it becomes calcified and stops growing on their reaching adulthood
eschar the thick scab which forms over full thickness burns
escharectomy surgical removal of an eschar
escharotomy incising an eschar so that it is split down to the deep soft layers
esophagus the gullet, that part of the upper gut tube from **pharynx** to stomach
evaporation changing from water in the fluid state to water vapor or gaseous state – to dry out
eversion lifting of the outer rim of the foot
excise/excision to surgically cut out
expiration to breathe out
exploration surgical searching and examination
extension increase what is already existing, eg., an incision, an infective process. When used to describe joint movements, it means the straightening out of a joint
extensor muscle producing extension
exteriorization bringing out from inside the body to the outside – like exteriorization of a loop of intestine
external fixation a technique for stabilizing bone fractures by external devices. Popularly referring to the external fracture fixators using pins and bars like the Hoffman, the Orthofix, the ASIF frame, but any pins in the proximal and distal fragments could also be held together with plaster of Paris, or tubes of orthopedic cement; see also **transfixion pins**
extra outside, extraperitoneal means outside the peritoneum

F

facial the face
fasciitis inflammation of fascia, usually due to infection
fascia muscle fascia is the fibrous layer that separates the muscles from the **subcutaneous** layer; fascia can be very thick like the thigh fascia, or so thin that it is scarcely visible in some parts of the body
fascicle (of nerve) small bundles of nerve fibers which together form a nerve

fasciotomy dividing and splitting open the fascia, so as to **decompress** a muscle compartment of a limb
fatal leading to death
feces stools
femur/femoral the thigh bone, or describing the region relating to the thigh bone
fermentation the process where yeast acts on **carbohydrates,** breaking them into smaller sugar molecules, a process which uses oxygen and produces **carbon dioxide**
fetus/fetal the unborn baby
fibrinolysis clot dissolution
fibrous a structure is said to be fibrous if it contains an abundance of fibers
fibula/fibular the outer and thinner bone of the leg
fistula a track leading from a body cavity, organ, tube, sac, to the skin surface
flechette projectile with dart-type steering devices
flexion bending a joint so that the **distal** part comes towards the **proximal** part
flexor muscle that brings about flexion
Foley (catheter) urethral catheter named after its inventor. It has an inflatable balloon at its tip to prevent it slipping out and is therefore self-retaining
French (size) a system of sizing the diameters of catheters and tubes
frontal the forehead

G

g (gram) a unit weight, one ml of water weighs one gram
G (size of needles) needle and cannula sizes, the larger the G the thinner the needle – standard intramusular injection needles are between 19 + 21 G, large IV cannulas should be at least 14 or 16 G, for blood **transfusion**
gangrene dead tissue, organ necrosis
gastric stomach
gastrostomy a surgical opening made between the stomach and skin, so that food solution could be given to the stomach, bypassing the mouth and **esophagus**
gelatin a protein derived from boiling **collagen,** after cooling the liquid sets to form a jelly-like material
gelatinization the process of making gelatin-like substances
genital reproductive organs, sex organs
Gigli (saw) orthopedic chain saw
globe of eye the eyeball
glucose a six-**carbon** sugar formed from breaking down carbohydrates. Glucose is the form of fuel used in the body to produce energy
gluteus/gluteal the large buttock muscles, or describing the buttock area
glycerol a chemical produced by chemically splitting fat
glycogen animal starch. Glycogen is the form in which **carbohydrate** is stored in the liver and muscles
graft tissue or synthetic material used to cover or make good a defect. It could take the form of skin graft or bone graft. Blood transfusion is also a graft
Gram (classification of bacteria) by using the gram-stain technique, bacteria are divided into those which retain iodine-treated, crystal violet stain even after washing with alcohol – gram-positive; and those which do not retain the stain – gram-negative.
granulation pinkish buds of healing tissue rich in capillaries seen growing in excised and healthy wounds left open. When granulations are seen, the wound can be skin grafted; if left alone, granulation tissue becomes transformed into scar tissue in due course
guillotine an apparatus for beheading. When used to describe an amputation, it refers to the cutting off of a limb at the same level

H

hallucination to hallucinate is to see or hear people or things which are not present; hallucination is a psychotic state
halo large ring over the head
hamstring (muscles) the muscles at the back of the thigh, they flex the knee and extend the hip
hematocrit also called packed cell volume, it measures the proportion of red blood cells in relation to the fluid of the blood, and should be about 34 normally
hematoma collection of blood, blood clot outside the blood vessels
hematuria blood in the urine
hemi- half
hemicolectomy removing part of the **colon,** eg. the ascending colon as in right hemicolectomy, or the descending colon as in left hemicolectomy
hemithorax half the **thorax,** either to the left of the **mediastinum** or to the right of it
hemoconcentration increasing proportion of blood cells in relation to the **plasma,** as in **dehydration.** Blood becomes more **viscous,** and there is increased tendency to clot
hemodilution blood becomes more fluid as the proportion of blood cells decreases, as in **Ringer** infusion
hemoglobin the iron-containing protein in red blood cell which carries oxygen and gives the blood its red color

hemolysis under certain conditions, the cell walls of the red blood cells rupture, and their contents escape into the plasma
hemostatic ability to stop bleeding
hemothorax bleeding into the **pleural cavity**
hepar/hepatic liver
heparinization giving of heparin to prevent **thrombus** formation inside the vascular tree
hernia protrusion of an organ or tissue through an abnormal opening or a weak point, eg. the **peritoneal** sac and abdominal contents pushing out through a weakness in the abdominal wall
herniation forming a hernia
hilum the "eye", a gap or opening in an organ where vessels enter and leave, such as hilum of kidney, liver, lungs
horizontal parallel to the horizon
hormone biologically active agents secreted by **endocrine glands** and released into the bloodstream so that they could be carried to exert effects on distant target organs
hyper- increased
hypermetabolism increased **metabolism**
hyperosmolar increased **osmolarity,** increased molecular concentration
hypertension increased blood pressure
hyperthermia body-core temperature above normal
hypertonic (solution) more concentrated than blood
hypertrophy increase in size of an organ
hyperventilation to overventilate, drawing in large volumes of air, or increasing the speed of breathing
hypo- decreased
hypoglycemia decreased glucose in the blood
hypo-osmolar decreased molecular concentration
hypoperfusion decreased blood flow through an organ
hypotension low blood pressure
hypothermia central body temperature below normal
hypotonic (solution) less concentrated than blood
hypovolemia decreased blood volume
hypoxemia low oxygen content in blood
hypoxia low oxygen tension

I

i.m. intramuscular, into muscle
i.o. intraosseous, into bone
i.v. intravenous, into vein
ileum the distal part of the small intestines where maximal absorption of food nutrients takes place
ileus, paralytic a state where the intestines become **paralyzed** and non-functional, resulting from non-mechanical causes
ileus, obstructive a state of non-functioning of the gut resulting from prolonged overactivity of the gut to overcome an obstruction; after some time, the gut packs up from fatigue and enters a **paralytic** state
iliac the ileum or the **pelvic** walls
immobilization to keep still, to prevent motion
immune system the system which defends the body against infection and includes the white blood cells, the lymph nodes and reticulo-endothelial system which produces the cells forming **antibodies** against bacteria, virus and **toxins**
immuno-protein an **antibody**
implosion to suck in, collapse inwards
incision a surgical cut
infarction tissue death through the blood supply being cut off
inferior below
infiltration (X-ray) this refers to the tissue of an organ becoming solid, dense on X-ray appearance. It can occur with infection, **hematoma,** injury, tumor
infiltration spread, eg. to spread a drug by injection into a layer of tissue
inflammation tissue reaction to infection, injury or **allergy,** consisting of redness, swelling, increased temperature and pain
inflate/inflation to blow up with air or fluid, as inflating a balloon
inorganic describing objects derived from non-living sources
inspiration to breath in, draw in air
inter- between
internal inner, inside a surface
internal fixation holding a fracture together by fixing it internally with nails, screws and plates inside the limb
interosseous between bone
intestinal the gut from below the stomach, consisting of the small and large intestines
intra inside
intramedullary inside the **medullary** canal of long bones
intramuscular inside muscles
intraosseous inside bone
intraperitoneal inside peritoneum
intravenous inside veins
intubation to insert a tube
invaginate (suture line) to close over
ischemic decreased blood flow
iso- same as
isometric same length
isotonic same concentration as blood

J

jejunostomy opening into the jejunum for the purposes of feeding, or diverting intestinal contents
jejunum proximal small intestine beginning just after the **duodenum,** and extending to the beginning of the **ileum**

K

kcal (kilocalories) 1000 calories
keloid hypertrophic scar
kg (kilogram) 1000 grams
kilocalorie 1000 calories
Kirschner wire stiff pointed wire which can be drilled directly into bone or bone fragments
kwashiorkor protein-calorie malnutrition, starvation where the deprivation of protein is worse than that of **calorie**

L

L (lumbar) the loin, the part of the trunk linking chest to the pelvis
lactase enzyme which converts lactose into user-friendly glucose
lactose milk sugar
laminectomy removing the posterior arch or lamina of the vertebra (to decompress the spinal cord and nerves within the spinal canal). See also **vertebra**
laparotomy surgical opening into the abdominal cavity
laryngoscope an endoscope with light source and a blade to direct an endotracheal tube into the **larynx** and **trachea**
laryngotomy an emergency procedure, to make an opening through the skin into **larynx** to let air into the lungs
larynx the voice box, at the beginning of the **trachea**
laser light of a certain wavelength is concentrated into a non-divergent beam. Laser has the ability to cut and burn tissues precisely
lateral to the outside of, away from the midline
legume beans, peas and other seeds of the family of plants which are **nitrogen** fixing
lesion a diseased area
ligament a fibrous band which strengthens a joint, either outside or on the joint capsule
ligate to tie
ligature a tie, a knot
lobe a part of an organ like a lobe of the lung, the liver, the brain, the kidneys
logistics organization and delivering of supplies and services
longitudinal lengthwise

M

m (meter) 100 centimeters
mm (millimeter) one thousandth of a meter
malabsorption impaired **absorption** of food nutrients from the intestine
malleolus the knuckles, the "eye" of the ankle
malnutrition insufficient nutrition
mamma/mammary breast
mantle (on bullets) the metal case which coats bullets
marasmus protein-calorie malnutrition, starvation where there is deprivation of both **calorie** and protein
maxilla/maxillary the cheek bone
media (of an artery) the muscular middle layer of artery
medial towards the midline
median central
mediastinum the midline structures between the right and left **hemithorax**, consisting of heart, **aorta, caval vein,** the **trachea** and the lung **hilum**
medulla (of bones) the central cavity of long bone, containing marrow, sandwiched between two layers of cortical bone
mega one million, 5 mega IU penicillin means 5 million IU penicillin
mental describing the mind
mesentery the peritoneal fold which suspends the small intestines and parts of the large intestines from the abdominal wall
mesh (skin graft) passing a skin **graft** through a machine which produces multiple, small, longitudinal cuts on it, allowing the skin graft to be stretched to twice, three times, or even seven times its size – hence 2:1, 3:1, 7:1 mesher. The cuts also allow drainage through the graft to the outside
metabolism chemical processes in the body which produce energy to sustain life
metacarpal (bone) the small long bones of the palm
metatarsal (bone) the small long bones of the foot
mg (milligram) a thousandth of a gram
micro- one millionth of, in popular term: "tiny, very small"
micro-circulation the blood circulation through the **capillary** vessels
micropore (filter) a filter used to filter particles and clots from blood during transfusion
mineralization (of bones) refers to the deposition of calcium crystals in bones, a process which gives bone its strength

mobilization to move a patient or a limb
molecule a basic unit of atoms held together, each molecule then forming a unit of a chemical
monitor to watch, to observe
mortality death rate
mortar a grenade launcher
motor function muscular and skeletal function resulting in movements
MUAC stands for mid-upper arm circumference
mucosa the mucus membrane lining body tubes like the urinary collecting system, the vagina, the oral cavity, the inner lining of intestines which secretes digestive juices, and carries out nutrient **absorption**
mucus a thick and slimy secretion of the mucosa
myocardium/myocardial the heart muscle
myoplasty an operation using muscles for reconstruction, such as closing an amputation stump, using a muscle flap

N

n.p.o. nil per orum, meaning to take nothing by mouth
naso-gastric nose to stomach. This is one way of introducing a tube into the stomach so that the stomach contents could be sucked out, or feeding could be carried out through the tube in patients who are unable to swallow
necrosis tissue death
necrotizing spreading necrosis
nephrectomy removal of kidney
nephrostomy surgically making a hole into the kidney **pelvis** so that urine could be drained out, eg., via a tube to the outside
nerve block anesthetic technique where the entire area innervated by a **sensory** nerve is made numb by injecting **anesthetic** at the nerve to temporarily block its ability to conduct impulses to the brain
neurology the study of the nervous system
neuroma a benign nerve tumor. Neuroma can form after an injury by numerous nerve bodies regenerating in unorderly fashion; it can be very tender and painful
nibbler an instrument developed to take bites out of bone
nitrogen element found in all living organisms. The amino acids from which protein is made, all contain nitrogen. The excretion of nitrogen by the urine reflects the degree of body protein breakdown
non-traumatic usually known as atraumatic. It applies to surgical techniques aiming to cause as little injury or trauma to the tissues as possible. This is achieved by careful handling of tissues, **dissection** with sharp blades, avoidance of tissue crushing, preservation of blood supply to the operated tissues
nucleus (of cell) a rounded, membrane-bound compartment of the cell which contains the chromosomes (genetic material)

O

olecranon the upper end of the **ulna** bone of the forearm. It forms part of the elbow joint, and the other side is for the attachment of the powerful **triceps** muscle tendon
oliguria decreased production of urine
omentum the **peritoneal** fat fold hanging down from the stomach and transverse large intestine in front of the small intestines
ophthalmology specialized medicine and surgery of the eye
ophthalmoscope an instrument with a light source for looking into the back of the eye, so that the **retina,** the optic nerve and the blood supply to the eye could be seen
oral mouth
oral airway an airway put into the mouth to ensure clear passage of air into the **pharynx** and **larynx.** It is designed to put the tongue out of the way
orbit/orbital the eye socket
organic originating from living matter
orthopedic surgery of the musculo-skeletal system
orthosis appliance worn as splints for joints
osmosis the passive transfer of water **molecules** across a **permeable** membrane dividing two compartments with different solute concentrations. Water will pass from the less concentrated solution to the more concentrated one until the concentration finally becomes equal on both sides of the membrane
osmotic pressure the pressure exerted across a membrane by the solutes; the more concentrated the solution, the higher the osmotic pressure
osseous bone
osteomyelitis bone and bone marrow infection
osteoporosis reduction in quantity and quality of bone
osteotomy "incision" or cutting bone with a saw or chisel to produce a surgical break
otoscope/otoscopy an instrument for looking into the external ear canal and eardrum
ovary female gland which secretes the female hormones as well as releases ovum (female reproductive cell)
oxygenation process of adding oxygen

P

palmar the palm of the hand
palpation to feel

pancreas gland behind the stomach which secretes digestive juices to the gut, and the **hormone insulin** to the blood
paradoxical breathing breathing which contradicts normal pattern. It refers to a segment of fractured chest wall which moves in the opposite way to the rest of the chest wall with each cycle of breathing in and out
paralysis loss of **motor function,** usually due to nervous system damage like a central stroke, or a nerve being out of action
paramedic traditionally means a health-care worker who works in adjunct to medical practitioners
parasite an animal, plant or micro-organism which lives in and/or off another creature (host), and draws its nourishment from it. Parasites range from worms to bacteria, to some insects
parboil partly cooked by boiling with water
parenteral the giving of drugs, nutrients and **vitamins** by routes other than the enteral (the intestine and mouth). Thus parenteral could be through the veins, **intramuscular, intraosseous**
paresis motor weakness, incomplete **paralysis**
patella kneecap
pediatric refers to medical treatment of children
pelvic cavity the lower part of the trunk which is enclosed by the pelvic bone. It therefore contains loops of intestines, the **rectum,** bladder, **prostate** in males, the female organs, and the large pelvic vessels and nerves
pelvis the large bone ring where the lower limbs meet the spine and trunk
pelvis (of kidney) the proximal part of the urinary collecting system
penetrating (injury) injury caused by outside sharp object penetrating the skin into the body – gunshot wounds and missile injuries. See also **blunt injury**
penis male copulatory organ, which also contains the **urethra**
per- for/by
percussion to strike quick, light blows onto hollow air-filled organs which produce a drum-like sound. If the organs or cavity becomes filled with fluid – like bleeding into the **peritoneal** cavity, or becomes solid like lung infection – the percussion note becomes dull, and a clinical diagnosis could be made
perforation a hole through the full thickness of a wall, eg., of the stomach wall, intestinal wall, blood vessel wall
perforator a tool for making a perforation
perfusion the passage of blood through an organ or a limb
pericardium the covering of the heart
perineum the lower end of the trunk which lies outside the **pelvic** outlet. It consists of the genitalia, the anus and the soft tissues bounded laterally by the ischial bones
periosteum the outer lining covering bones. Periosteum is thick and well developed in the young, and becomes thinner with age. It becomes very important in the formation of bridging **callus** after fractures
peritoneum/peritoneal the lining of the abdominal cavity which covers most of the abdominal contents. At places it doubles up on itself forming a **mesentery**
peritoneal cavity the cavity lined by the peritoneum
peritonitis inflammation of the peritoneum, which may be infective or chemical
permanent lasting
permeability porosity, describes the readiness with which membranes allow water and other **molecules** to pass through
peroneus the lateral leg muscles responsible for foot extension and **eversion**
peroperative during the operation
phantom (pain) ghost, describes pain felt in a limb which has already been amputated
pharynx back of the nose and **oral** cavity leading down to the larynx
phlegmon pus forming infection and thickening of skin and **subcutaneous** tissue, usually caused by staphylococcus bacteria
phrenic nerve the nerve to the diaphragm, with roots from cervical 3, 4, and 5
physical relating to the musculo-skeletal system, or to physics
physiology the study of body functions in living things
physiotherapy treatment with physical measures like heat, ultrasound, massage, changes in temperature and physical activity
placenta a blood-rich organ developed in the pregnant uterus to carry out nutrition, exchange of oxygen and **carbon dioxide** for the **fetus**
plantar the sole of the foot
plasma expander solutions of large **molecules** which increase the circulating volume of the blood by increasing its **osmotic pressure,** thus drawing in fluid from the tissues outside the blood vessels
plasma the fluid part of the blood which contains proteins and salts, excluding the blood cells
plaster of Paris also called Gypsona, the active chemical substance is calcium sulphate dihydrate. When mixed with water, it becomes creamy and can be molded into any shape conforming to the body contours. It sets into a hard mass during a chemical reaction forming a conforming cast

platelet (blood) small fragments of large cells called the megakaryocytes. Platelets circulate in the bloodstream and are important in stopping bleeding by causing blood to clot, as well as small vessels to constrict

pleura the lung membrane, the inner part of it lines the lung, the outer part lines the chest cavity. The two layers of pleura are held together by vacuum between them

pleural chest

pleural cavity the two (right and left) lungs-containing cavities of the chest lined by pleura, separated by the **mediastinum** and the heart

plexus (cervical, lumbar) a network of nerves

pneumonia lung infection

pneumothorax air in the **pleural** cavity, often resulting in lung collapse

p.o. post-operative

popliteal the back of the knee

portal vein vein carrying blood from the intestines to the liver

post- after

postburn after burn

posterior the back of

post-operative after operation

postural drainage drainage by position

PR pulse rate

pre- before

premedication medication given before adminstering an anesthetic, which usually helps to calm the patient down and decrease secretions

pre-operative before operation

pronation to turn the forearm so that the palm faces downwards

prone position to lie face downwards

prostate male gland situated round the outside of the bladder neck and the pelvic urethra

prosthesis an artificial limb

proximal towards the head

psychological mental, also mood

psychosis mental illness, where patient has no insight into his own condition

pubic (bone) the front of the pelvis

Q

quadrant (of abdomen) one of the four quarters of the abdomen

quadrate four-cornered shape

quadriceps the extensor of the knee joint, the quadriceps muscle is composed of four bands of muscle meeting at the **patella** and patellar tendon

R

radiate to spread outwards in a radial fashion

radical treatment which aims to do as much as possible thus radical surgical excision means excising as much tissue as possible with a wide margin

radius/radial one of the two forearm bones, and in the **supinated** position is the lateral of the two

rasp bone file

ray (of hand/foot) the **metacarpus/metatarsus** and its corresponding digit forms one ray

receptor a tissue or cell target on which **hormones** and **enzymes** can exert their action

rectovesical pouch the space between the **rectum** behind and the bladder in front

rectum/rectal the last 10 inches of the large intestine terminating in the **anus**

reduce/reduction (fracture management) to straighten and restore to correct position a broken bone

reflex, of nerves automatic nerve action in response to certain stimuli

regeneration (of tissue) recovery, regrowth of tissues

rehabilitation to restore function to a limb, to return a person to his full before-injury status to his community

renal kidney

resection to cut off a section of

respiration breathing

retard to slow down

retention (of fluid) keeping back of fluid resulting in swelling of cell, limb or organ. It may be localized to an organ or cavity as in ascites of the abdomen, or collection of fluid in the **alveoli** of the lungs, or it may be generalized as in edema caused by heart, liver or kidney diseases

retina the inner lining of the inner part of the eye bulb consisting of specialized nerve ends capable of reading light signals

retraction (of tendons) after a tendon is cut off, the proximal end is still attached to the muscle which therefore pulls the cut tendon end proximally

retraction (during surgery) to hold tissues away from the operative field so that they do not get in the way of dissection or surgery

retractor instrument for retraction during surgery

retro- behind

retroperitoneal behind the **peritoneum**

Ringer a solution of **electrolytes** which is **isotonic** to human blood

RR respiratory rate

rupture to burst, tear

S

S (sacrum) the pelvic part of the spinal column
saline/normal saline salt solution, normal saline describes saline which is isotonic to blood, and is 9 mg NaCl/ml fluid
scapula the shoulder blade
sciatic sciatic nerve is the large nerve from the **sacrum** which runs down the back of the thigh and supplies the muscles and skin of the leg and foot
sclera the thick fibrous wall of the eyeball
scrotum the sac and skin covering the testes
section (gynecology) to deliver a baby through an incision through the wall of **uterus**
sedatives drugs which calm
sensor function touch, pain, temperature, vibration and position sense are all sensor functions
sepsis/septic infection
septicemia bacteria and their **toxins** from a septic source entering and multiplying in the bloodstream produce septicemia. Apart from local sepsis, the patient also becomes generally feverish and ill
septum a partition wall
sequestrectomy removal of infected, dead bone
serosa (of the intestine) the outermost layer of the intestine merging with the **peritoneum**
serum the non-cellular part of the blood
shunt divert
SIB (ventilation) self-inflating bags
sigmoid S-shaped section of the descending large intestines
silicone an inert material which has rubber qualities, but does not provoke the reaction to rubber, hence its usefulness as indwelling catheter, joint spacers
sinus, of the nose the large air-filled spaces in the bones around the nose
sinus, of the brain the venous channels inside the skull; they are thin walled and easily damaged in surgery or fractures, resulting in massive bleeding
spasm sustained muscular contraction
spatula spoon
spectrophotometer an instrument which measures the intensity of the light transmitted by a substance in different part of the light spectrum, thus allowing its identification and analysis, eg. **hemoglobin** analysis
spica (plaster) a special plaster cast for the hip where the affected leg as well as the opposite leg are **immobilized** to control hip and thigh fractures; it is like plaster pants
spinal vertebral
spine the backbone
splenectomy removing the spleen
static motionless
Steinmann (pin) special 3-5 mm pin used for transfixing bones
stenosis narrowing
sterilization the process of rendering free of micro-organisms, bacteria
sternomastoid muscle the muscle on both sides of the neck attached to the mastoid process, the clavicle and the sternum
sternum the longitudinal piece of bone attached to the ribs in the front of the chest, behind which lies the heart with its **pericardium**
steroid corticosteroids, **hormones** secreted by the adrenal cortex which are important for coping with stress
stethoscope an instrument for listening to the heart, lungs and bowels
stirrup a metal loop which could be fastened to a pin, and **traction** applied
stoma intestinal opening to the outside
stricture narrowing
stylet a metal tube or needle with a sharp end inserted through a soft cannula to help its easy insertion, once the object is cannulated, the stylet may be removed
sub- under
subclavian describes the large vessels under the **clavicle** destined for the upper limbs
subconjunctival underneath the conjunctiva
subcutaneous the layer of tissue just under the skin, it is usually fat, with some fibrous tissue
superior above
supernatant the top fluid left after mixtures are left standing for some time, heavy particles sinking to the bottom
supination to place the forearm so that the palm faces upwards
supine position to lie on the back
suppuration infection with pus formation
supra- above
suprapubic above the **pubic** bone
sympathetic nervous system see **autonomic nervous system**
syndrome a clinical complex
synovial fluid joint fluid
synovium the membrane which lines the joint and secretes the joint fluid
synthesize to make
synthetic artificial
systolic during the contraction of the heart **ventricles**

T

tachycardia fast heart rate

tampon a gauze pack or ribbon tucked into a bleeding space

tamponade inserting a tampon to stop bleeding

tangential parallel to the surface, thus tangential excision means excising parallel to the surface. Tangential hit means the bullet impact is parallel to the surface

tarsorrhaphy stitching the eyelids together so that the eye is closed

tarsus of eye the eyelid plate

TBSA total body surface area

temporal the temple on the side of the face and skull

temporary for the time being only

tenotomy to divide a tendon

tension in describing solids, it refers to the state of being stretched, pulled apart, tautness. With reference to gases, it means the pressure exerted by the gas

Th (thoracic), thorax that half of the trunk above the diaphragm and below the neck

thoraco-abdominal chest and abdomen

thoracotomy to open into the chest

thrombosis formation of a blood clot inside the blood vessels

thrombus a blood clot forming inside a blood vessel. The thrombus will not only obstruct blood flow, but it may become detached and, in the case of venous thrombus, carried centrally with the venous blood flow into the lungs, where it then causes lung tissue death by blocking **pulmonary** vessels – pulmonary **embolus**

thyroid (gland, cartilage) endocrine gland in the front of the neck which secretes the hormone thyroxine

tibia/tibial the shin bone

tone (of muscles) strength of contraction. Contraction of muscles produces its tone; muscle relaxation abolishes its tone

topical local

tourniquet a band, cuff, tubing tied round a limb intended to stop the blood flow into the rest of the limb

toxic poisonous

toxin a substance produced by bacteria that is poisonous to other cells or organs

trace mineral trace minerals refer to a group of elements which are essential to body functions, but needed in minute quantities only

trachea/tracheal the large wind-pipe from **larynx** leading into the chest, when it branches into the main **bronchus** to the right and left lungs

tracheostomy a surgical opening made in the wind-pipe so that a breathing tube could be inserted

traction pull, stretch. To put a fractured limb on traction is to pull on its **distal** end, steady its **proximal** end either by gravity or counter-traction. Traction overcomes the muscle pull, allowing the fracture ends to reduce

tranquilizer a drug which calms a person down

transfixion (bone pins) transfixion pins, like the Steinmann pins, strong Kirschner wires, have sharp ends so that they can perforate through cortical bones. See also **external fixation**

transfusion to give fluids directly into the blood, fluids can be **Ringer,** nutrient solutions, whole blood, **plasma**

transplant to take tissues from one part of the body (donor area), or from some other person (donor) and **graft** it onto another area (recipient area or recipient). Examples of autotransplant (same person) are blood autotransfusion, skin grafts, flaps, bone grafts. Examples of tissues and organs from a different donor are **cross-matched;** blood transfusion, cadaveric corneal grafts, kidney and heart transplant from live donors

transverse to lie across the body at right angles to the longitudinal axis

trauma insult, injury

trephination technique of drilling holes in the skull

triage sorting out casualties into groups – those in need of immediate treatment, those whose treatment is less urgent, those who need minimal or no treatment, and those whose injuries are so severe that they have to be allowed to die comfortably

triangular three-cornered

triceps (of the arm) the large muscle at the back of the arm inserting into the olecranon; it has three muscle bellies which merges into a tendon

triceps (of the lower leg) the group of muscles at the back of the lower leg (gastrocnemius and soleus) that make up the **Achilles tendon** and flex the ankle (and the knee)

trochanter at the junction of the neck of the **femur** with its shaft, the bone becomes enlarged into two prominences: The larger one is the greater trochanter into which the large hip **abductors** are attached; the smaller is the lesser trochanter to which the ilio-psoas, the hip **flexor** is attached

turbulence (of the bloodstream) disturbance, uneven movement. Ideally blood should flow in a smooth streamlined manner inside blood vessels, but if there is narrowing or kinking of the vessel, this smooth flow becomes disturbed, hence turbulence occurs

U

u.p.h. urinary output per hour
ulcer a hole. Skin ulcer is a hole in the skin, duodenal ulcer is a hole in the **mucosa** of the **duodenum;** when ulcers become deeper and deeper, and reach the other side of the wall, perforation results
ulna/ulnar the medial of the two forearm bones, when the forearm is placed in supination
umbilicus the navel
uremia when the kidneys are not functioning properly, **nitrogenous** waste products are not excreted via the urine. They therefore accumulate in the blood producing a state of uremia – with high blood nitrogen in the form of urea. Isolated raised blood urea (uremia) may not be due to the kidneys malfunctioning, it may also be due to excessive nitrogen production due to tissue breakdown after injury
ureter the tube or duct leading urine from the kidney to the bladder
urethra the tube leading urine from the bladder to the outside
urography X-ray examination the kidneys, ureters and bladder by i.v. injection of contrast that becomes excreted by the kidneys
USP (dimension of sutures) USP stands for United States Pharmacopeia
uterus the womb

V

vacuum a void, an empty space. A term also used for spaces that do not contain air
vagina female passage linking the uterus to the external **genital** opening
vagus nerve the tenth cranial nerve, it is part of the **autonomic nervous system** and is a parasympathetic nerve. Its secretions oppose the effects of the sympathetic nervous system – hence if the sympathetic nerves to an organ cause the vessels to contract, the parasympathetic will cause them to relax
vascular relating to blood vessels
vascularize to bring blood vessels into tissue
vasoconstriction blood vessels have muscle walls, and when they contract, the vessels become thinner – vasoconstriction
vasodilation the opposite of vasconstriction, the blood vessel muscle wall relaxes, and the vessel opens up and expands its inner size
veins blood vessels which bring blood from the tissues and organs back to the heart
venesection to draw blood from a vein
ventilation the mechanical part of breathing consisting of inspiration (inhalation) – drawing air into the lungs, and expiration (exhalation) – the process of pushing air from the lungs to the outside
ventricle/ventricular the muscular chamber of the heart which pumps blood into the arteries. The right **ventricle** pumps blood out to the lung artery and the lungs; the left ventricle pumps blood into the **aorta**
vertebra a unit bone of the spine. The spine is formed of multiple vertebral bones all linked to each other. Each vertebra has a body in front, facet joints behind and to the sides, and a spinous process towards the skin
vertical upright
vesica cyst, also commonly means the bladder
viability ability to survive
viscosity fluid thickness
vital functions the functions essential to life – like breathing, heart beat, heat regulation
vital essential for life
vitality life, **energy**
vitamin chemical substances needed in small quantities in everyday food for metabolism and health
vocational professional, career, job
volar the palmar aspect of the hand
volume therapy treatment by giving fluids to replace fluid lost from the blood circulation

W

wedge resection to take out a wedge of organ due to injury or disease
wedge fracture a compression fracture of the **vertebral** body resulting in the **anterior** edges of the body being pressed together, so that side X-rays show a wedge shape

X

xiphoid the terminal part of the **sternum.** It is usually a flexible separate piece of cartilage shaped like an arrow head

Z

zygoma malar, the bony cheek prominence

Index

'... "War Surgery, field manual" will be a help to health care providers who have to treat war casualties in less than ideal circumstances. This is something that is not easily obtained from the literature, and this book will be an important contribution to the field.... It will help establish a standard of care for military and non-military health care providers who are required to treat patients under these conditions.'

John A. Weigelt MD, Professor and Vice Chairman,
Department of Surgery, University of Minnesota, USA

'... "War Surgery, field manual" is a practical and detailed handbook for surgeons and other medical staff who find themselves having to meet the needs of injured people in situations of war. The book not only covers assessment and procedures for surgical intervention in a wide variety of circumstances, but also includes wealth of information on the organization of war medical service and on approaches to setting up forward clinics. The manual will prove to be an indispensable tool for surgeons and surgical assistants who find themselves in circumstances of war. As far as I know, there is no other manual in existence which covers this information with such depth and clarity.'

David Werner, the author of "Where There is No Doctor"

'MMC has used the procedures recommended in "War Surgery, field manual" in building a network of mobile forward clinics. Since 1989 our field clinics have provided limb and life-saving surgery to more than 5,500 war casualties from the combat grounds in Central and Eastern Afghanistan. With its simple terminology and clarifying illustrations, the book has proved to be very useful in training of graduate as well as non-graduate medical staff.'

Dr. Assadullah Reha MD, Medical Director of Mujahed Emergency Medical Center (MMC), Jalalabad, Afghanistan

ISBN 983-9747-12-6 Pb, 983-9747-14-2 Hb